SURVIVAL AND SPRING PRODUCTION OF WHITE CLOVER IN ASSOCIATION WITH BAHIAGRASS IN RESPONSE TO GRAZING MANAGEMENT

BY

BELSON HESTEN DZOWELA

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1984

It's your turn now, Madalitso

and

Titha.

Mine is over.

ACKNOWLEDGMENTS

The author's studies at the University of Florida were supported by the United States Government's Agency for International Development/ Malawi Government, through their trustees, the University of Florida's International Programs Center for Tropical Agriculture of the Institute of Food and Agricultural Sciences at Gainesville. It gives the author great pleasure, therefore, to record his sincere gratitude for all the financial support. He is also humbly indebted to the Government of the Republic of Malawi, for granting him leave of absence from the Civil Service to study in the U.S.A.

The author is thankful to Dr. W. R. Ocumpaugh (now at Texas A & M University Agricultural Research Station, Beeville, Texas) and to Dr. G. O. Mott, who both served as chairmen, respectively, providing vital technical and professional guidance, constructive suggestions and criticisms throughout the author's 3-year stay at the University of Florida. He extends his appreciation also to Drs. W. G. Blue (Soil Science), J. E. Moore (Animal Science), J. H. Conrad (Animal Science), and O. C. Ruelke (Agronomy), members of the supervisory committee,for their collaboration at various stages of his studies culminating in the preparation of this dissertation.

He also thanks Dean, Kent, and Bruce, personnel at the Beef Research Unit for their field support. To his fellow students and friends, Evans, Enock, Eric, Anderson, Afete, Alex, Douglas, James, Batson, Charles, Johnson, Pickford, and Arlan who all helped with

field work and botanical hand separation, he is grateful, for single-handed, the task was formidable.

Last, but not by any means least, he wishes to record his thanks to his dear wife, Elie T. Nyamuhome, for her love, understanding and the unflinching moral and physical support throughout his studies, especially for her willingness to make the hard decision to temporarily abandon the caring of their two children, back home in Malawi, when she joined the author-husband in the latter half of his stay in the U.S.A. Most importantly, he dedicates the work embodied in this dissertation to his two children, Madalitso (daughter) and Titha (son), who both suffered the emotional and psychological blow of temporarily living without Dad and Mom.

TABLE OF CONTENTS

		PAGE
ACKNOWLEDGMENTS		iii
LIST OF TABLES		vii
LIST OF FIGURES		ix
ABSTRACT		xii
CHAPTER I	INTRODUCTION	1
CHAPTER II	REVIEW OF LITERATURE	4
	Pasture Components	4
	Bahiagrass	4
	White Clover	6
	Grass-White Clover Associations	9
	Effect of Grazing	11
	Effect of Treading	13
	Seasonal Persistence of White Clover	14
	Growth in White Clover	19
	Regrowth in Forage Legumes	21
	The Role of Non-Structural Carbohydrates and Crude Protein	21
	Seedling Recruitment	23
	Pasture Management and Survival	26
	Role of Soil Nutrition	27
	Role of Diseases and Pests	28
	Breeding Efforts with White Clover	30
CHAPTER III	MATERIALS AND METHODS	34
	Experimental Site Characteristics	34
	Pasture Establishment	34
	Experimental Design and Treatments	37
	Grazing Management	42
	Measurements and Recordings	42
	Total Available Forage Dry Matter	42
	White Clover Forage	44
	Survival Potential of White Clover	47
	Soil Seed Reserves	47
	White Clover Plants Living Through Summer/Fall	47
	Recruited White Clover Seedlings	48

PAGE

Disease and Pest Attack..... 48
Root and Stolon Rot Disease Monitor..... 48
Other Diseases and Pests..... 48
Soil Moisture..... 49
Total Non-Structural Carbohydrates and Crude Protein..... 49
Early Animal Exclusion Cages..... 51
Statistical Analysis..... 51

CHAPTER IV RESULTS AND DISCUSSION..... 54

Soil Moisture Differences on the Site..... 54
Total Available Spring Forage..... 54
White Clover Spring Forage..... 62
Survival Potential of White Clover..... 68
Soil Seed Reserves..... 68
Number of Perennating White Clover Plants.. 80
Number of White Clover Seedlings Recruited. 83
Disease Attack..... 86
Leaf Rust and Phoma Leafspots..... 86
Root and Stolon Rot Diseases..... 90
Ground Cover..... 93
White Clover Ground Cover..... 93
Cool Season Weed Species Percent Ground Cover..... 99
Pest Attack..... 99
Population of Grazing Snails..... 99
Leafeaters and Leaf Weevil Attack..... 104
Early Preclusion of Grazing..... 108
Total Non-Structural Carbohydrates and Protein 110

CHAPTER V SUMMARY AND CONCLUSIONS..... 113

Soil Moisture Difference on the Site..... 113
Total Available Forage in Spring..... 113
White Clover Spring Available Forage..... 114
Survival Potential of White Clover..... 114
Pest Attack and Grazing Snails Population..... 116
Disease Attack..... 116
Early Preclusion of Grazing..... 117
Total Non-Structural Carbohydrates and Crude Protein..... 117

APPENDIX..... 120

LITERATURE CITED..... 148

BIOGRAPHICAL SKETCH..... 162

LIST OF TABLES

TABLE		PAGE
1	Dates and rates of fertilizer application.....	35
2	Climatological data at the Beef Research Unit.....	36
3	Treatment combinations applied to the main plots.....	40
4	Relationship between disk meter readings (X_1) and dry matter ha^{-1} (Y_1).....	45
5	Relationship between visual (X_2) and actual estimates of percent white clover (Y_2) on a DM basis.....	46
6	Within pasture differences in soil moisture in spring between "wet" and "dry" (concentration on dry matter basis).....	55
7	Total available and white clover forage (kg DM ha^{-1}) on wet and dry sites and on herbicide treated subplots	61
8	Number of white clover plants perennating and seedlings recruited m^{-2} on wet and dry sites and on herbicide treated subplots.....	67
9	Linear correlation coefficients and probability levels of white clover yield with soil seed reserves, recruited white clover seedlings, live-over clover plants.....	69
10	White clover leaf rust and Phoma leafspot, root and stolon rot diseases attack scores (0-5) on wet and dry sites and on herbicide treated subplots.....	89
11	White clover and cool season weeds percent ground cover on wet and dry sites and on herbicide treated subplots.....	98
12	White clover pest attack scores (leafeaters and leaf weevils on 0-5 scale) and grazing snails numbers m^{-2} on wet and dry sites and on herbicide treated subplots	105
13	Total available forage, white clover yield, pest attack and disease attack score percentage increases over grazed pasture in spots excluded from grazing early in summer and fall.....	109

TABLE PAGE

14 Linear correlation coefficients between TNC and CP content of white clover stolons with soil moisture content..... 112

LIST OF FIGURES

FIGURE		PAGE
1	Schematic representation of design points based on a modified central composite design.....	39
2	Scheme of the treatments as applied to the subplots..	41
3	Grazing and sampling scheme employed during the experiment.....	43
4	Surface plot of total available spring forage in response to period of deferment and grazing pressure for April 1982.....	56
5	Contour plot of total available spring forage in response to period of deferment and grazing pressure for April 1982.....	57
6	Surface plot of total available spring forage in response to period of deferment and grazing pressure for April 1983.....	58
7	Contour plot of total available spring forage in response to period of deferment and grazing pressure for April 1983.....	59
8	Surface plot of white clover spring forage in response to period of deferment and grazing pressure for April 1982.....	63
9	Contour plot of white clover spring forage in response to period of deferment and grazing pressure for April 1982.....	64
10	Surface plot of white clover spring forage in response to period of deferment and grazing pressure for April 1983.....	65
11	Contour plot of white clover spring forage in response to period of deferment and grazing pressure for April 1983.....	66
12	Surface plot of white clover soil seed reserves in response to period of deferment and grazing pressure.	71
13	Contour plot of white clover soil seed reserves in response to period of deferment and grazing pressure.	72

FIGURE PAGE

14 Number of white clover soil seeds m^{-2} in response to period of deferment..... 73

15 Number of white clover soil seeds m^{-2} in response to grazing pressure..... 74

16 Number of white clover soil seeds m^{-2} in response to herbicide treatments..... 76

17 White clover soil seed germination budget in response to herbicide treatements (No. of seedlings germinated m^{-2})..... 77

18 White clover soil seed germination budget in response to grazing pressure..... 78

19 White clover soil seed germination budget in response to period of deferment..... 79

20 Surface plot of number of white clover plants perennating through summer-fall in response to period of deferment and grazing pressure..... 81

21 Contour plot of number of white clover plants perennating through summer/fall in response to period of deferment and grazing pressure (No. of plants $m-2$).. 82

22 Surface plot of white clover seedlings recruited in response to period of deferment and grazing pressure 84

23 Contour plot of white clover seedlings recruited in response to period of deferment and grazing pressure 85

24 Surface plot of leaf rust and Phoma leafspot attack scores (on 0 to 5 scale) in response to period of deferment and grazing pressure..... 87

25 Contour plot of leaf rust and Phoma leafspot attack scores (on 0 to 5 scale) in response to period of deferment and grazing pressure..... 88

26 Surface plot of root and stolon rot disease attack scores (on 0 to 5 scale) in response to period of deferment and grazing pressure..... 91

27 Contour plot of root and stolon rot disease attack scores (on 0 to 5 scale) in response to period of deferment and grazing pressure..... 92

FIGURE PAGE

28 Surface plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1982..... 94

29 Contour plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1982..... 95

30 Surface plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1983..... 96

31 Contour plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1983..... 97

32 Surface plot of cool season weed species percent ground cover in response to period of deferment and grazing pressure..... 100

33 Contour plot of cool season weed species percent ground cover in response to period of deferment and grazing pressure..... 101

34 Surface plot of grazing snails populations in response to period of deferment and grazing pressure. 102

35 Contour plot of grazing snails populations in response to period of deferment and grazing pressure. 103

36 Surface plot of leafeater and leaf weevil pest attack scores on white clover in response to period of deferment and grazing pressure..... 106

37 Contour plot of leafeater and leaf weevil pest attack scores on white clover in response to period of deferment and grazing pressure..... 107

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

SURVIVAL AND SPRING PRODUCTION OF WHITE CLOVER IN ASSOCIATION WITH BAHIAGRASS IN RESPONSE TO GRAZING MANAGEMENT

BY

BELSON HESTEN DZOWELA

April 1984

Chairman: G. O. Mott
Major Department: Agronomy

Florida Selection-15 (or Osceola), a new white clover (Trifolium repens L.) cultivar which resulted from mass selection to improve the persistence of this forage legume, was subjected to a grazing management study in association with bahiagrass (Paspalum notatum Flugge). The effects of summer-fall periods of deferment (40, 68, 96, 124, and 152 days after 20 June) and grazing pressure (levels of 500, 1000, 1500, 2000, and 2500 kg DM of post-grazing residue ha^{-1}), were studied on "wet" and "dry" sites. Included were three qualitative subplot treatments: (a) a herbicide, Banvel® (40.6% 3,6 dicloro-0-anisic acid), (b) a nematocide-insecticide, Furadan (10% carbofuran 2-3 dihydro 2,2 dimethyl-7-7 benzafuramyl methyl carbamate), and (c) a control of no herbicide/nematocide-insecticide application.

Total available forage and white clover herbage in 1982 and 1983 increased with decreasing residue but response to period of deferment reached a maximum value at 96 to 124 days for total available forage and 68 to 96 days for white clover.

White clover forage appeared to be directly influenced by summer-fall grazing management through its effect on survival potential. Soil seed reserves, seedling recruitment, live-over plants and ground cover were all at a high level under heavy grazing pressure (decreasing residue) and intermediate to short periods of deferment. The wetter site, because of better survival potential, resulted in large amounts of clover forage. Banvel®-treated plots, because they contained many seedling white clover plants, gave the smallest amount of forage. Both white clover survival potential and forage were inversely related to cool season weed species cover. While pest and disease attack was greater at more lax grazing management, the disease attack scores however recorded were generally low to cause much concern. The influence of both moisture conditions and herbicide/nematocide-insecticide applications were generally minimal. White clover stolon organic reserves (total non-structural carbohydrates and crude protein) contents in the spring were little affected by the grazing management of the preceeding summer-fall period. An accompanying small study in which the summer-fall grazing was terminated early, resulted in increased amounts of forage the following spring, but unless the forage was grazed during the late winter-early spring period, the clover component was heavily attacked by pests and diseases.

CHAPTER I
INTRODUCTION

Research to evaluate, develop, and manage tropical legumes for permanent pastures in Florida has been intensified in recent years. High production costs, especially N fertilizer, and characteristically low forage quality of subtropical grasses in peninsular Florida indicate tremendous potential from incorporation of summer legumes into permanent grass pastures (Pitman, 1983). Tropical summer growing legumes available commercially include the annual legumes, aeschynomene (Aeschynomene americana L.), the short-lived perennial legumes, phasey bean [Macroptilium lathyroides (L.) Urb.], and the perennial legume, 'Florida' carpon desmodium [Desmodium heterocarpon (L.) DC var. heterocarpon]. These legumes initiate growth in late spring, grow best in summer-early autumn, and succumb to the cold of the late autumn-winter season. Cool-season growing pasture legumes, such as white clover (Trifolium repens L.) fill the production gap in the winter-early spring period.

Grass-clover pastures are the basis of many livestock enterprises in temperate and subtropical areas of the world. This is particularly so because of the complementary use of N by the grass and clover in the system. The complementary growth rhythms of the grass and clover result in higher forage yields and a more uniform distribution of dry matter production throughout the year, than stands of either component. Because of the clover component when effectively inoculated with a

Rhizobium which fixes atmospheric N, grass-clover swards are capable of producing as much dry matter as pure grass swards receiving high amounts of inorganic N fertilizers. However, only when a stable association is maintained between the sward components are the full advantages of the grass-clover mixtures realized.

In the subtropical environments such as exist in north central Flordia, white clover behaves primarily as a reseeding annual. It grows mainly in spring, its frequency usually declines over summer and early fall, but increases over winter to reach a peak in spring. Growth is variable from year to year, depending on both spring rainfall and the amount of clover seed reserves present.

The persistence of white clover in grazed pasture may be attributed to low mortality of the original plants, and survival of stolons through the summer and fall. On the other hand, it may persist depending upon regeneration from seed produced from the preceeding year. Survival dynamics of white clover in association with tropical grasses are presently little known. Environmental factors such as soil moisture and stolon and root rot diseases seem to be generally implicated. The increase in white clover in the cooler months appears to be a function of both the growth of surviving stolons and regeneration from the soil seed pool. Both these vary considerably from site to site under the influence of recurrent climatic factors and grazing management systems employed.

Efforts to improve clover performance through selection for survival during the summer have resulted in the release of the white clover cultivar, Florida Selection-15, in north central peninsular

Florida. To assess its survival ability through summer and fall, the selection has been tested under a wide range of summer and fall grazing managements in association with bahiagrass (Paspalum notatum Flugge) cv. Pensacola at the University of Florida's Beef Research Unit. This grazing management study is the subject of the work currently reported.

CHAPTER II
REVIEW OF THE LITERATURE

Pasture Components

Bahiagrass

Bahiagrass (Paspalum notatum Flugge) is a creeping perennial with stolons and rhizomes. The stolons, which are firmly pressed onto the soil surface have short internodes and root freely from the nodes which also develop leaves and shoots. Bogdan (1977) has noted that it occurs naturally in a wide area extending from the southern U.S.A. and Mexico to Buenos Aires in Argentina and to the West Indies. It has been introduced to other tropical and subtropical areas of the world extending through Africa and Asia to as far east as southern Japan and Australia. In the U.S.A. it is widely cultivated in the southern states and more especially in Florida, where extensive research with the grass has been conducted.

The grass is polymorphic and the species now under discussion, P. notatum, has short racemes and small spikelets 2.5 to 3 mm long. Leaves are short and narrow. It is a tetraploid apomict with chromosome number of 2n = 40. It is believed to have originated from the tropical and subtropical South American environments of Argentina, Brazil, Bolivia, and some West Indian islands. The material from which cv. Pensacola was derived was found near Pensacola, a town in the panhandle of the state of Florida, on the coast of the Gulf of Mexico, where it is believed to have been introduced accidentally

from Argentina by ships importing Argentinian cattle (Burton, 1967). Pensacola is the best cultivar widely grown in the U.S.A and introduced elsewhere (Bogdan, 1977). It provides good grazing for a long period with peak growth and production in late summer and early autumn. Seed is commercially available, and there are some 350,000 seeds kg^{-1}.

Maximum recorded yields have come from Zimbabwe (formerly Rhodesia) where Mills et al. (1973) realized 20.7 Mg DM ha^{-1} from 900 kg applied N ha^{-1}. Yields generally depend on the level of N; but 3 to 8 Mg DM ha^{-1} are not uncommon from moderately well fertilized grass grown under suitable climatic conditions (Bogdan, 1977). Animal production is reasonable, and in Florida liveweight gains of 670 kg ha^{-1} have been recorded (Haines et al., 1961).

Bahiagrass does well in the tropics and subtropics with moderate or high rainfall but it can also tolerate droughts because of its long roots which can penetrate deep into the soil (Bogdan, 1977). Temperature requirements for normal development are high although maximum tillering has been observed at 20 to 25°C (Kiwamura and Yamasaki, 1972 cited by Bogdan, 1977). It withstands cold weather better than other species such as P. dilatatum. Bahiagrass tolerates some degree of frost and Jones (1969) in Queensland, Australia, has seen it survive temperatures as low as -10°C.

The grass is an aggressive species and when fully established leaves little room for the development of legumes, and mixtures with leguminous plants have met with only moderate success. However, white clover and Lotononis bainesii, both low creeping perennials, increased

the yields of total herbage and the content of crude protein of mixtures compared with bahiagrass grown alone (Bogdan, 1977; Whiteman, 1980). Other creeping perennial legumes such as the perennial peanut (Arachis glabrata Benth.) have given satisfactory results in Florida (Prine, 1964). In those areas of subtropical U.S.A., where bahiagrass is dormant due to suboptimal or freezing temperatures in the autumn and winter, cool-season growing legumes have shown promise with bahiagrass, and white clover has shown its potential in this respect (Donnelly and Hoveland, 1966).

White Clover

White clover is a diverse species exhibiting many different forms with varying physiological and nutritional adaptations to specific environments. These range from the erect, lax-leaved "Ladino-type" plants exhibiting few, but large, plant parts, to the very prostrate "Kentish-type" plants with many small organs (Brougham et al., 1978). These morphological differences enable the species to adapt to a wide range of habitats. Populations exist that will withstand severe winters, hot dry summers, extreme grazing pressure, and low fertility soils.

The history of white clover in the U.S.A. is somewhat obscure, but it was reported by Carrier and Bort (1966) to have probably been introduced by the colonists from the old world and that it was subsequently well established in the Ohio and Kentucky areas (Leffel and Gibson, 1978). The clovers of these early days were probably the wild, small, prostrate and winter-hardy types. Records of the large white

clover type, Ladino, were first made by the North Carolina Station in 1891 (McCarthy and Emery, 1894). After the initial failures, adaptation of Ladino white clover to the northeastern, north central, and southeastern U.S.A. was realized about the 1930s (Ahlgren and Fuellman, 1950).

Daday (1958) has presented an account of the geographical distribution of white clover within and beyond the temperate regions of the world. The genus Trifolium constitutes annuals and perennials of about 300 species distributed mainly in the temperate regions, particularly in the Mediterranean area. The species T. repens is found from the Arctic circle throughout the temperate regions of the world. It is found in subtropical regions such as Gulf Coast of the U.S.A. and Queensland, Australia. It has been tried in a number of other tropical countries with various success. It is a creeping perennial species in the temperate region but in the subtropics it may grow as an annual or perennial depending upon moisture in valleys receiving spring and autumn rainfall (Whiteman, 1980). It rarely grows in areas receiving less than 875 mm in the subtropics (Humphreys, 1974).

Near the equator the species is found at altitudes ranging from 1600 to 3000 m in Colombia and mainly as a morphologically similar white clover, T. semipilosum in the East African highlands (Crowder, 1960). Trifolium repens appears to be limited geographically only by the cold of the Arctic, the drought of the deserts and the heat and plant competition of the lowland tropical humid forests (Leffel and Gibson, 1978).

The agricultural importance of white clover, other than that of direct consumption by livestock comes about because of the N-fixing ability of the symbiotically associated Rhizobium (Brougham et al., 1978). The fixed N improves the nutritive value of the forage and it enhances the growth of the companion grass in mixed grass-clover swards. The amount of symbiotically derived, harvestable N from a pasture system varies from 142 kg ha^{-1} $year^{-1}$ in newly established pasture systems to 45 kg ha^{-1} $year^{-1}$ in oldest established pastures (Emeades and Goh, 1978). As much as 680 kg fixed N ha^{-1} on an annual basis has been reported in New Zealand under favorable climatic and management situations. Tropical grasses-white clover pastures have been shown to fix as much as 140 to 500 kg N ha^{-1} $year^{-1}$ (Dobson and Beaty, 1980; Curll, 1982). The variation in the amount of N fixed depends upon the density of clover stand, growth, length, and characteristics of the grazing season, soil fertility, and effectiveness of inoculation.

Perennial legumes such as white clover are generally believed to improve the energy, N, and mineral composition of seeded grass pastures. In the southern states, such pastures replace ranges for some 7 to 12 months of the year (Dobson and Beaty, 1980). The amount of white clover grown in pasture mixtures has varied widely. In the late 1940s, white clover attracted considerable research attention as did legumes in general, but in the 1950s and during most of the 1960s, the application of inorganic N on seeded grass pastures increased and consequently interest in production of white clover decreased. As interest in growing cattle in the southeastern

U.S.A. later increased, production of white clover including that produced on range has correspondingly increased (Dobson and Beaty, 1980). By the 1970s, interest in high rate N usage on pastures decreased and interest in including white clover in the forage mix was renewed considerably.

White clover is generally considered to be one of the most nutritious legumes (Gibson and Hollowell, 1966; Koger et al., 1961). In contrast to grass forages, variation in chemical concentrations between white clover samples is usually small (Wilkins et al., 1958) and is considered to be caused by white clover dehiscing dead leaves leaving only green forage. The P, Ca, and K concentrations of white clover have been reported to exceed 0.35, 1.50, and 1.50%, respectively (Miller, 1958; Stewart and Bear, 1951). White clover generally produces low forage yields but growing it with a grass prevents bloat in ruminants, improves forage quality, and increases yields (Daugherty, 1956).

Grass-White Clover Associations

Grass-clover pastures are widely known as the basis of many sheep and/or cattle enterprises in temperate, subtropical, and high altitude tropical environments of the world. The stimulus to superior animal performance afforded by the inclusion of a clover component in the grass sward has been documented in reviews by Reed (1972), Thomson (1977, 1978), and Curll (1982). The complementary use of N by the grass and clover components and their seasonal complementary growth rhythms in these environments can result in higher forage yields

(Harris, 1968; Orr and Laidlaw, 1978; Curll, 1982) than pure stands of either component. Grass-clover swards involving mostly temperate grasses and a few tropical grasses have been shown to produce as much dry matter as pure grass swards receiving between 140 and 300 kg inorganic N ha^{-1} (Holmes and Aldrich, 1959; Reid, 1972; Dobson and Beaty, 1977; Morrison et al., 1979).

The benefits of grass-clover mixtures are only obtained if a suitably stable association is maintained between the component species. Harris and Thomas (1973) have described this association as a state of dynamic equilibrium in which there is no permanent or marked dominance of one component or suppression of the other. Curll (1982) suggested that a clover content of 30 to 50% throughout the year is the most desirable mixture. However, the grass and clover contents do vary considerably in grazing situations and the clover content particularly, may be as low as zero at certain times of the year in the more humid tropical environments. Jones (1982) considers that total forage yields on offer, in mixed swards, in excess of 3000 kg ha^{-1} could depress both stolon survival and seedling regeneration. This is the reason why in coastal subtropical Australia the recommendation that the mixed pastures be well grazed throughout the year, has been widely accepted. This management usually favors both stolon survival over summer and seedling regeneration in winter. However, under heavy grazing there is a risk of causing an unfavorable shift in the composition of the associated species of grass. Also, clover survival during dry summer conditions may be poorer following greater soil moisture stress in closely grazed pastures (Jones, 1982).

Effect of Grazing

In grazing situations, there is treading and return of excreta as well as defoliation. Simulations of the effects of defoliation on botanical composition by cutting have been made world-wide, but these attempts have been largely unsuccessful because cutting precludes the selective and non-uniform aspects of grazing. It is not uncommon that defoliation by grazing animals cannot be separated from treading and excreta return. The composite process of grazing must, therefore, be used to describe the effects of its defoliation component especially in terms of frequency (determined usually by height at grazing or by date or time), intensity (determined by height of stubble), or management (rotational or continuous grazing, with or without fertilization).

The grass component in grass-clover mixtures is commonly shown to be favored by lenient or infrequent grazing while frequent close or hard grazing favors the growth of clover (Brougham, 1959, 1960). Where clover is unable to raise its leaf canopy, lenient grazing reduces the light intensity at the clover canopy level, thereby reducing clover growth and clover plant numbers (Stern and Donald, 1962). In contrast, increased light penetration caused by close grazing management can lead to the initiation of new stolons, increase the number of small leaves and where the terminal bud is removed, cause prolific branching of the stolons (Curll, 1982). All these are morphological adaptations to help withstand defoliation.

The effect of grazing regimes on the grass-clover swards can vary considerably with grass species or cultivar used. For instance,

Brougham (1959, 1960) used the hybrid ryegrass (Lolium perenne x L. multiflorum) which is less persistent during summer and less tolerant of hard grazing than perennial ryegrass (L. perenne). Wolton et al. (1970) like many others earlier, found that perennial ryegrass persisted or increased under hard grazing compared to lenient grazing and contrary to Brougham's (1959, 1960) findings, they reported that the content of white clover decreased with hard grazing.

If either grass or clover is preferred in the mixture and is selectively defoliated, its abundance relative to the other component species may be reduced. Variation in sward structure and the distribution of species within the sward canopy have been suggested as likely to influence the opportunity for preferential species selection (Harris and Thomas, 1973). The erect growth habit of some grass components in grass-clover associations, for example Nui ryegrass, produces a more open pasture with larger interplant spaces compared with the uniform density of a Ruanui ryegrass. As a consequence, clover stolons are more vulnerable to selective grazing in Nui than in Ruanui ryegrass-white clover pastures, where stolons have some protection from the associated grass (Harris et al., 1977; Widdup and Turner, 1983).

Curll and Wilkins (1983) found than when clover was preferred, its selective defoliation at high stocking rates, contributed to a substantial reduction in the clover content in perennial ryegrass-white clover swards. At lower stocking rates, on the other hand, selective defoliation appeared to be matched with clover regeneration.

Clover was better able to survive selective defoliation by developing a prostrate, small-leaved,short-petioled stature in the swards where the grass canopy was not high enough to shade it.

The importance of the defoliation process on the effect that differences in stocking rate have on grass-clover swards was demonstrated by Curll and Wilkins (1981). They separated the effect of defoliation on perennial ryegrass-clover swards from the effect of treading and excreta return by using "graze through cages" (Smith et al., 1971). Where swards were defoliated only, the weight of clover on offer increased by 65% during the grazing season when stocked at 25 yearling sheep ha^{-1}, but decreased by 85% when stocked at two times that rate. Differences in defoliation between stocking rates have a greater influence on clover survival than either treading or return of excreta.

Effect of Treading

In mixed grass-clover pastures, grasses are generally more tolerant of treading than clovers (Brown and Evans, 1973; Edmond, 1964). Difference in species tolerance has been related to the quantity of sclerenchyma tissue in plant parts and to the extent that more susceptible parts of the plant, i.e., growing points, leaf buds and surface roots, are exposed to damage by the hoof (Brown and Hoveland, 1972). Treading damage to plant parts and compaction of the soil by treading have been shown to reduce plant growth and persistence (Akiyama and Kubo, 1978; Wiersum, 1979).

The stoloniferous growth habit of clover has been suggested as a reason for its greater susceptibility to treading damage compared to grass (Swetham, 1973). The ability to maintain its plant population under treading is related to its potential for establishing new clover plants at each node and its ability to increase the density of these nodes per unit length of stolon (Swetham, 1973). Clover's tolerance to treading is greater when grown in association with grasses than in monocultures. This is presumably because the grass protects the clover from treading damage thereby increasing its relative competitive ability in these pasture situations.

Seasonal Persistence of White Clover

In temperate environments, white clover acts more as a perennial plant, but in tropical and subtropical areas as exist in southeastern Australia, southeastern U.S.A., and high elevation areas in the tropics it behaves more as a winter annual (Hollowell, 1966). Several mechanisms account for its persistence from season to season. Foremost of these are (a) seedling regeneration from soil seed reserves and/or (b) the ability to survive as individual plants. The ability to persist is dependent upon recurrent droughts and other environmental factors which impose severe limitations (O'Brien, 1970).

The survival and population dynamics of white clover in association with a typical tropical forage/pasture grass have scarcely been explored. There have been disjointed reports concerning the survival of the primary taproots in the temperate areas of the U.S.A.

(Westbrooks and Tesar, 1955), seedling regeneration in subtropical U.S.A. (Blaser and Killinger, 1950), and the quantity of white clover soil seed reserves of pastures in the U.K. (Milton, 1943) and New Zealand (Hyde and Suckling, 1953). Recently, work from southeastern Australia environment (Jones, 1980, 1982) has indicated wide seasonal fluctuations in the frequency of white clover, characterized by a decline over summer and early autumn followed by an increase over winter peaking up in the spring. It has been shown in this Australian work that the presence of white clover is more affected by site and climatic conditions. The increase in the cooler months is due both to growth of surviving stolons and the regeneration from seed. There appears to be a substantial increase in yield of white clover corresponding with improved stolon persistence over summer, as plants arising from seedling regeneration in winter only initiate stolons in spring (Jones, 1980). It appears that selection pressure for improved stolon persistence over summer would result in a competitive advantage the following winter-spring season.

Further work on the survival of white clover has been reported from New Zealand (Hay, 1983). It has been shown that there is a large proportion of stolons buried at all times of the year and more especially in the late autumn-early spring period. This burial of stolons is primarily by worm casts and it is an annual event. For white clover stolons to persist from year to year, it appears crucial that they have the ability to establish growing points on the soil surface. This is achieved partially by the buried primary stolons initiating branch stolons that are capable of growing vertically

through the soil to the soil surface and by redirection of stolon apices to the soil surface. The importance of continuity of stolons, in this respect, has been reported by Turkington et al. (1979). Its role in aiding stolon persistence varies considerably with genotype and environmental factors such as moisture (Brougham et al., 1978).

Spring white clover growth was reported to be significantly correlated with soil moisture and temperature (Crowder and Craigmiles, 1960). Without irrigation, clover growth is related to residual soil moisture during the spring, and the proportion of white clover in the sward was found to be strongly dependent upon rainfall in subtropical Australia. Here, the effect of rainfall was more important on white clover survival than either stocking rate or P fertilization (Robinson, 1973; Hutchinson, 1970).

High temperatures have been reported to reduce white clover growth regardless of moisture. Decreased growth at elevated temperature is primarily ascribed to increased respiration (McWilliams, 1978). Clearly temperature also influences several aspects of morphology. High temperature tends to increase the rate of leaf appearance and leaf area expansion, whereas cold temperature, on the other hand, favors the development of laterals (Mitchell, 1956; Alberda, 1957). In Trifolium subterraneum, it has been particularly demonstrated that maximum yield of swards grown over a range of temperature (15-30°C) was inversely correlated with temperature (McWilliams, 1978).

The optimum temperature for the growth of roots tends to be lower than that for shoot growth (McWilliams, 1978). White clover shows maximum root weight at temperatures of about 7.5°C below the

optimum soil temperature for shoot growth (Davidson, 1969). This means that in the early spring root growth is more active and competes more effectively for available carbohydrates and stored reserve carbohydrates. As the season progresses, soil temperatures become more favorable for growth of the shoots and their growth accelerates at the expense of roots. High soil temperatures may be lethal if sustained over long periods during the warm humid conditions of the summer months in the subtropics and tropics.

In Florida, white clover has been commonly reported to have occasionally a winter and spring annual growth as well as a perennial growth. Classical studies by Blaser and Killinger (1950) indicated the effects that temperature and sod management have on seedling recruitment from volunteer white clover. Poor and variable germination was recorded at temperatures above 21.6°C. Close clipping of the sward or burning resulted in lower minimum soil temperatures than under a tall canopy. They concluded that close-grazing in late summer or early fall would enhance the germination of clover soil seed reserves, an important factor for persistence from season to season as we have seen above.

Kalmbacher et al. (1980) reported that clover stolons did not persist through the summer and fall to the extent of providing adequate amounts of forage the following year. When they compared three legumes, alfalfa (Medicago sativa L.), red clover (Trifolium pratense L.), and 'Tillman' Ladino white clover, they found that although both alfalfa and red clover established more readily, these two legumes were the first to die out in the hot humid environment. In terms of

seedling density (seedling m^{-2}) and forage dry matter yield, Ladino white clover was lowest after alfalfa and red clover, respectively. Good clover populations throughout the summer have been reported by Kretschmer (1958) only where adequate lime and P applications were made. In associated swards of bahiagrass-white clover, proper legume seeding occurred only when the bahiagrass canopy was removed before November.

Furthermore, Kalmbacher et al. (1979) found that in bahiagrass-white clover mixed swards, snail (Polygyra cereolus Muhlfeld) attack was contributing more significantly to clover losses than in mixtures involving red clover and alfalfa. When the bahiagrass sod was burnt following desiccation with a herbicide there was a 98% mortality rate for P. cereolus in the pasture and a better clover seedling survival rate. Seedling regeneration ability of clovers in central and northern Florida was studied by Hodges et al. (1953) and Killinger (1970). It was found that the Florida synthetic type of white clover was higher yielding and more persistent and reseeded more satisfactorily than either Ladino, Louisiana S1 and 'Nolins' improved white clovers.

Several studies have been conducted to date at the University of Florida. A comparison of companion grasses with white clover by Koger et al. (1961) found that bahiagrass appeared to encourage better clover stands than did pangolagrass (Digitaria decumbens Stent) and 'Coastal' bermudagrass (Cynodon dactylon L.). A subsequent study of beef production potential of grass-clover associations by Koger et al. (1970) also established that while forage yields of pure pastures were similar to those of the best grass-clover pastures, beef production from pure

grass pastures was more costly due to N fertilization and supplemental feeding. Management studies showed that grass-clover systems produced consistently more forage than those under a renovation program or under irrigation (Killinger, 1977). Koger (1977) concluded that white clover thrived better under grazing than when cut. He further noted that fertilizer requirements for clover pastures under grazing management were less than usually recommended and that reproductive performance of beef cattle improved when clover was included in the pasture. In Florida, while several legumes are available for a variety of soils in the state, especially when moisture is adequate, only white clover in combination with Pensacola bahiagrass has performed very successfully under consistent management on poorly drained Spodosols in the north central peninsular Florida (Blue, 1979).

Growth in White Clover

The patterns of seasonal growth in white clover have been studied by Beinhart (1963). In field studies, selected stolons on plants of several clones were observed from March through to September. The stolon was chosen as a unit for study of growth because it possesses certain advantages over entire plants. It is easily observed and its development can be monitored, measured and described as a chronological sequence of specific events (Beinhart et al., 1963). It was observed that rapid growth commences in late March when the primary stolons radiate outwards from the plant center. For a period of 4 to 6 weeks these primary stolons account for nearly all the leaf area produced. Following this, secondary stolons emerge from the primaries at a rapid rate from mid-April through to May. Throughout the summer

branching of primary nodes produced in April and May-June period is low and most of the leaf area at this time comes from the April-May branches.

The last phase of development occurs in September, during which time tertiary meristems become active and contribute a large portion of the total leaf area harvested at the end of September. The dominant portion of foliage subsequently is produced by tertiary meristems arrayed in relative profusion along many secondary stolons. Spring and autumn (fall) growth is, therefore, characterized by active branching and there are periods in which the total number of active meristems greatly increase. By contrast branching is reduced to a low level during the summer. Haplin et al. (1963) have noted that the summer is the period in which diseases are most destructive; the number of active meristems diminishes and leaf areas are reduced correspondingly. The key to increased summer persistence appears to be increased summer branching ability. Nevertheless, it has been established by Beinhart (1963) that carbohydrate reserves are never a limiting factor to summer branching. It has also been observed that prolific spring flowering is inversely correlated with persistence by limiting the number of active vegetative meristems present in summer similar to the effect of adverse temperatures and light intensities. Flowers as well as branches arise in leaf axils. Because a single node may only give rise to either a flower or a vegetative branch, each flower produced precludes one potential vegetative branch. White clover flower heads are produced on peduncles that are longer than leaf petioles. The inflorescence is usually round with an average of

75 individual flowers. The white color of the corolla is responsible for the common name, white clover, of the species. The fruit is a membranous pod with three or four seeds. Flowers usually open in a progressive pattern from bottom to top for a period that may be as long as 1 week. After fertilization, usually through the pollination help of insects such as bees, seeds mature in 3 to 4 weeks; the process is accelerated by high temperature (Gibson and Hollowell, 1966).

Regrowth in Forage Legumes

In forage legumes, regrowth potential is an added advantage for persistence after defoliation and/or grazing. It is mediated in the shoot apex which remains vegetative whereas axillary buds develop an inflorescence. The primary source of energy for regrowth is the nutrient reserves in the plant, translocated from storage organs to the growing sink or from photosynthesizing tissues remaining from defoliation (Smith, 1981; Blaser et al., 1966). A good correlation exists between forage yield and persistence on the one hand and vigorous regrowth on the other. The amount and type of non-structural carbohydrates, number of growing points and residual leaf area after the defoliation treatment will influence regrowth (Weinmann, 1961; Smith, 1981; Graber, 1931; Booysen et al., 1963; Jewess, 1972; Kretschmer, 1976; Valle, 1977; Andrade, 1979; Saldivar-Fitzmaurice, 1983).

The Role of Non Structural Carbohydrates and Crude Protein

Stored organic compounds, such as carbohydrates, fat, and proteins, serve as food reserves for plants at times when photosynthesis cannot

supply sufficiently for maintenance and growth (Trlica, 1977; White, 1973; Weinmann, 1961; Smith, 1981). These reserves provide a source of energy and a source of molecules for growth when plants are completely defoliated, but a definite role in regrowth of partially defoliated plants has not been proven (May, 1960; Jameson, 1964). In addition to a role of reserves in regrowth of completely defoliated plants, reserves are utilized by perennials during the winter (Menke and Trlica, 1981).

Root reserves typically decrease following harvest of aerial growth and this decrease may imply a role for reserves in regrowth. Whether or not used for regrowth directly, reserve level may serve as a measure of plant vigor following grazing (Trlica, 1977; Daer and Willard, 1981).

Plants in general can be classified on the basis of the type of non-structural carbohydrates that are accumulated; whether starch or fructosan accumulators (Smith, 1968). They may also be classified on the basis of the type of structural carbohydrate; xylose is the predominant structural carbohydrate in fructosan containing plants while glucose is predominant in starch containing plants (Ojima and Isawa, 1968).

Fructosan is the predominant non-structural polysaccharide in the herbage of temperate origin grasses and is water soluble as is amylose starch (especially in hot water). The predominant non-structural carbohydrate in the herbage of grasses of tropical origin is sucrose with readily soluble starch (Wilson and Ford, 1973). In contrast, starch that accumulates in the herbage of legumes and tropical origin forage grasses is largely water insoluble.

Numerous comprehensive reviews have been written on the carbohydrate reserves of plants in relation to phenological development, vigor, production, and defoliation (Cook, 1966; White, 1973; May, 1960; Weinmann, 1961; Trlica and Singh, 1979). The accumulation of total non-structural carbohydrate (TNC) in undisturbed plants shows a strong seasonal trend in most species. It generally increases in summer and late fall. During winter months it declines followed by a further decline as a result of spring flush growth. Crown-tissue crude protein is high early in the spring, reaches a minimum in late spring and then increases moderately in the fall (Stout et al., 1983).

Close and frequent defoliation of clover significantly reduces the carbohydrate content of stolons and roots. Blaser et al. (1966) and Hojjati et al. (1968) have reported that the concentration of TNC in storage organs such as roots, crowns, or stolons can be reduced considerably by N fertilizer because more assimilates are utilized in shoot growth, leaving relatively less to be channelled to the storage organs. Moderate shading as occurs from competitive companion grasses also decreases the concentration of TNC (Burton et al., 1959).

Seedling Recruitment

Study of the dynamics of survival in grazed tropical pasture systems basically hinges upon population dynamics of the constituent species. It is concerned with the recruitment and death of plants; density being the accumulated net result of these processes (Harper, 1977; Jones and Mott, 1980). Agronomists often consider pastures as

botanically stable or unstable. Stability is assessed in terms of frequency of appearance and fluctuations in botanical composition. In mixed swards, the constant turnover of individual plants enables an agronomic definition of one important aspect of good pasture management as that which aids the recruitment and persistence of the desired species. In contrast, Gardener (1982) has defined poor management as one that hastens the death and population erosion of preferred species and/or aids their replacement by inferior species. A successful tropical or subtropical pasture legume must be able to withstand severe interplant competitive stress in some situations and severe defoliation in others. There is a wealth of published information indicating that variation in grazing intensity can affect legume longevity (Leach, 1978), seedset (Taylor and Rossiter, 1974; Jones and Jones, 1978), and hence recruitment potential.

The diversity of views on the "annual" or "perennial" nature of white clover stands has been discussed by Hollowell (1966). It is generally accepted that clover basically persists as a perennial in temperate areas such as Wales in the U.K. (Turkington et al., 1979) and as an annual in subtropical areas such as southern Florida (Blaser and Killinger, 1950). However, there are large differences between years in the perennation of clover over summer. Survival is poorer on dry sites in very dry years, but other factors such as rotting of stolons and roots infected by Pythium middletonii are involved (Irwin and Jones, 1977). Infection by nematodes could also be a contributing factor. In Florida, Jones (1982), quoting A. E. Kretschmer, reported that flooding could also cause white clover death over summer.

Seedling recruitment is a function of clover seed content in the soil (Jones and Evans, 1977; Jones, 1982). Soil seed content, however, varies from site to site depending upon moisture conditions. It is generally higher on moist sites. In addition to withstanding effects of grazing and other forms of environmental stress, a persistent legume species must be able to regenerate vegetatively or by seed. It has been shown in subtropical Australia that reserves of white clover seed in the top 10 cm of soil beneath good legume stands could be as high as 1300 to 6000 seeds m^{-2} (Jones and Evans, 1977; Jones, 1980, 1982). No seed was found beneath stands from which the legume had been eliminated by overgrazing. Furthermore, while a systematic quantification of seedling survival dynamics in established pastures is little known, the report from subtropical Australia has clearly shown that during the initial stages of establishment, seedlings are susceptible to competition. If a pasture is grazed lightly enough to allow seeding, the same pasture may severely limit survival of new seedlings unless special management procedures are adopted (Sproule et al., 1983).

Grazed pastures provide the cheapest source of feed for ruminants, during much of the year in most parts of the world, and are harvested by the grazing animal without large costs in non-renewable resources. It is imperative, therefore, that management of pastures be improved to increase the economy of plant production and the efficiency of pasture use and improving the standards of human nutrition and welfare. In modern husbandry, livestock practices have largely removed regulation of the size of domestic herbivore populations from control by natural means. It is not uncommon that livestock numbers exert a powerful influence on the vegetation of intensively managed

pastures. In improved pastures containing both grasses and legumes the influence of frequency and intensity (grazing pressure) shows its maximum complexity. This is because the reactions of the grass and legume to defoliation differ markedly. A particular grazing management, in such associations can often give one or the other species a competitive advantage so that in time it dominates the sward.

Vegetational changes in pastures occur as a result of the action of several possible mechanisms (Kydd,1966). Plants may possess attributes such as low palatability or accessibility which prevent removal by grazing. Animals differ in their individual grazing behavior with some species or individuals exercising greater dietary selection than others. Botanical composition of mixed pastures can be influenced by the level or spatial distribution of plant nutrients (Wolfe and Lazenby, 1973a, b). Finally, climate and the physical environment exert powerful direct and interactive effects with the other three above.

Pasture Management and Survival

It is generally accepted that the rates of survival and recruitment of species can be drastically altered by pasture management. For instance, grazing pressure has been reported to affect plant longevity (Jones and Mott, 1980). The survival of a species such as Siratro (Macroptilium atropurpureum) plants is much poorer in heavily grazed than lightly grazed Siratro-Nandi setaria (Setaria sphacelata) pastures. On the other hand, the dynamics of Danthonia caespitosa pasture was unaffected by grazing or no grazing (Williams,

1970). Longevity of Lucerne (Medicago sativa) too is affected by grazing systems as much as it is by grazing pressure (Leach, 1978).

Grazing management primarily affects seed set, seedling regeneration, and vegetative propagation. In Siratro, for instance, flowering and seed set are linearly related to yield at flowering time (Jones and Jones, 1978) and seed set is favored by light grazing. On the contrary, in Townsville stylo (Stylosanthes humilis) pasture, legume seed set is favored by heavy grazing. Direct grazing of the seed heads in some clovers (Trifolium hirtum and T. subterraneum) can also affect botanical shifts to the disadvantage of the legume species (Taylor and Rossiter, 1974). Seedling regeneration also is reported to respond to grazing management. With both white clover (T. repens) and Kenya white clover (T. semipilosum) seedling emergence is reported highest in well-grazed areas (Jones, 1982). Grazing pressure influences seedling survival also. Siratro seedling survival is reportedly very poor at light stocking rates (Jones and Mott, 1980).

Fertilization as a management factor can also have a profound influence on botanical compositions of pastures (Bryan and Evans, 1973). Where nutrient deficiencies are extreme, survival will be enhanced by fertilizer dressings. Johansen et al. (1977) have reported that the persistence of Neonotonia wightii is limited by Mb deficiency.

Role of Soil Nutrition

Effectively nodulated legumes in monoculture may not respond to N fertilization (Lee and Smith, 1972), although there have been

instances of positive response in well-nodulated T. repens and T. subterraneum (Helyar and Anderson, 1970). Excessive N supply can reduce plant growth, and the species least responsive to N at lower levels of N supply show the greatest sensitivity to N toxicity (Wilson and Haydock, 1971). High N levels can impair the legume-Rhizobium symbiosis (Dart and Wildon, 1970). Excess NH_4 within the plant can have specific effects but sometimes the toxicity may arise from secondary effects such as salt damage or induced pH changes inside and outside the root (Russell, 1973).

In white clover-based pasture systems, the legume in the association is a poor competitor for P (Jackman and Mouat, 1970), S (Walker and Adams, 1958), and N (Walker et al., 1956). The poor competitive ability of white clover for nutrients normally limits plant growth. It is related to root characteristics such as root cation exchange capacity and/or root morphology. Recent studies (Brougham et al., 1978) have shown that white clover in association with grasses develops thicker roots, shorter root hairs, and lower frequency of root hairs than the companion grasses. These characteristics place the legume at a competitive disadvantage to explore effectively the soil volume and act to its detriment in obtaining scarce supplies of nutrients, such as P, that do not diffuse readily.

Role of Diseases and Pests

Leffel and Gibson (1978) have discussed the diseases and pests of white clover. Amongst the diseases of importance are stolon and root rots which are known to seriously deplete stands of white clover.

Notably, species of Fusarium, Rhizoctonia, Collectotrichum, Leptodiscus and Curvularia are involved as part of the stolon and root rot complex that involves environmental conditions. It has been noted by Menzies (1973) that these rots, although extremely common, frequently do not become effectively pathogenic unless the clover is exposed to severe stress such as summer drought. Sclerotium rolfsii Sacc. may be prevalent in the south during the hot humid periods. S. trifoliorum Eriks occurs mostly in the northern areas under snow or in the dense stands during winter or early spring.

Virus diseases are common in white clover especially by the third year of the stand. The viruses that affect white clover singly or in combination include the alfalfa mosaic, white clover mosaic, clover yellow mosaic, white clover yellow vein mosaic, red clover vein mosaic, and peanut stunt virus. These viruses are spread by grazing, mowing, and insect vectors. They all have a significant influence on the persistence of white clover stands.

Foliar pathogens include pepper spot, Leptosphaerulina trifolia (Rostr) Petr. during cool wet weather; Cercospora leaf and stem spot, Cercospora zebrina Pass throughout the season; Curvularia leaf spot, Curvularia trifoli (Kauff.) Boed. during warm humid weather; sooty blotch, Cymadothea trifoli (Pers. ex. Fr.) Wolf. during cool seasons; and rusts, Uromyces trifolii var trifolii-repentis (Liro) Arth. in late summer and fall. Considerable loss of leaf and reduction of the forage quality is caused by these diseases.

White clover leaves are especially susceptible to the potato leafhopper, Empoasca fabae Harris. Feeding by this insect causes

stunting and a reddening-bronzing and browning of the leaves. Spittlebugs, Philaensis spumarius (L.) stunt and cause a rosetting of terminal growth. Clover leaf and alfalfa weevils, Hypera punctata F. and H. postica Gyll, respectively, are leaf feeders especially in early spring. Larvae of clover root curculio, Sitona hispidula F. feed upon the roots and introduce soil borne root rotting fungi to the root system thereby reducing the plant's survival potential. The seed crop in the south is threatened especially by the lesser clover leaf and clover head weevils, Hypera nigrirostris and H. meles, respectively. Larvae of these insects attack parts of the flowering head, stunting or destroying heads and preventing seed formation, thus affecting the quantity and quality of the seed bank.

Breeding Efforts with White Clover

The wide range of morphologic forms within T. repens is recognized in the classification of organic types as small, intermediate, or large according to several growth habits. The magnitude of variation within the species together with its wide geographic distribution, suggests that desirable phenotypic traits can be enhanced by plant breeding (Hollowell, 1951) techniques to yield white clover strains adapted to suit particular environmental stress. For this to be possible, identification of the available phenotypic traits is necessary.

For instance, Suzuki et al. (1958) estimated the heritability of some phenotypic characters in Ladino clover and suggested that selection be based upon an index derived from heritable characters correlated in some way with forage yield such as leafiness, a quality

easily perceived and defined. Several measurable traits contribute to leafiness including leaf number, leaf size, stolon elongation, and stolon branching frequency. Ahlgren and Sprague (1940), on the other hand, studied morphological variation in white clover and found that rapid spreading was associated with increased size of all plant organs but was generally accompanied by a reduction in number of leaves per unit area.

The importance of growth habit was studied by Yamada (1959) who compared the drought tolerance of "Oligophyllous" and "Polyphyllous" white clover plants; these types were comparable to "viney" and "non-viney" growth habits, respectively. It was reported that the polyphyllous plants had greater drought tolerance although they were leafier than the oligophyllous plants.

Furthermore, the importance of leaf area as a factor in plant growth rate has been stressed by Watson (1956) who stated that leaf area is a more important determinant of dry matter yield than is net assimilation rate. Beinhart (1962) used growth chambers to study the growth of white clover at different temperatures and light intensities and found that plant dry weights were proportional to leaf area over a wide range of environments. Differences in leaf area production have been used as an important basis for comparing different clones in breeding programs.

Since white clover is such an important pasture legume in eastern Australian and southeastern U.S.A. where it is grown in association with temperate and tropical grasses (O'Brien, 1970; Ostrowski, 1972), there has been renewed interest in recent years in this legume amongst

forage scientists. Breeding efforts in subtropical Queensland, Australia have led to the release of Trifolium repens cv. Haifa (Barnard, 1972) and T. semipillosum cv. Safari (MacKay, 1973) both of which were selected in an attempt to improve the performance of clovers in this region.

Selection work in north central peninsular Florida was intensified by Dean (1975) and Paim and Dean (1976) in an attempt to search for a more perennating white clover. This work in Florida was rewarded with the release of Florida Selection-15 white clover. A progressive study was initiated at the University of Florida's Beef Research Unit to test the selection under a wide range of summer and fall grazing managements in association with bahiagrass cv. Pensacola in 1979. First and second years' production data were subjects of two Master of Science theses by Davila-Calderon (1981) and Lopez-Nunez (1982). The salient feature arising from Davila-Calderon's work is that the area covered by volunteer clover in the plots previously treated with a herbicide to eliminate live-over clover plants, grew better at high levels of grazing pressure. He noted that there was a curvilinear relationship between white clover and residual dry matter with maximum values at levels between 1000 and 1500 kg og post-grazing residue DM ha^{-1}. The influence of the period of deferment treatments was less apparent.

Lopez-Nunez's work was in general agreement with Davila-Calderon's findings, although he reported a considerable reduction in seedling white clover yield and height in response to increasing periods of deferment. For instance, he reported that for each 28 days increase

in period of deferment, white clover yield reduction was of the order of 100 kg DM ha^{-1}. He also noted that seedling clover cover yield at the 1400 kg residue level was only 20% of that obtained at the 500 kg residue level. Perennial white clover yield, on the other hand, was reduced by 50% when the residue increased from 500 to 1400 kg ha^{-1}. He observed a better white clover stand in moist than dry experimental areas.

With the working hypothesis that some environmental factors affect the survival ability of white clover during summer in association with bahiagrass, and that grazing management accentuates the influence of such factors on the survival of white clover in these pastures, the present study was conducted. Specifically, it was designed to try and explain the mechanisms by which white clover survives in association with an aggressive tropical forage grass such as bahiagrass. Secondly, it was to study the effects of summer-fall grazing periods of deferment and grazing pressure on the survival mechanisms and yield of white clover grown in this association. Thirdly, it was conducted to study the influence of site conditions in terms of soil moisture regimes on the yield and survival potential of the white clover component. Finally, it was to study the spring yield production and survival potential of the white clover component in response to herbicide and insecticide-nematocide applications.

CHAPTER III
MATERIALS AND METHODS

Experimental Site Characteristics

The experiment was conducted at the University of Florida's Beef Research Unit, some 16 kilometers northeast of Gainesville. The site is a typical flatwoods (Spodosols) with poorly drained soils for a major part of the year. Davila-Calderon (1981), USDA (1982), Carlisle et al. (1981), and Coelho (1979) have described the soil as Pamona sand (sandy, siliceous, hyperthermic Aeric-ultic Haplaquod) in which the A-1 horizon (0-15 cm) is very dark gray sand and very strongly acid. Originally in its uncultivated state, the soil had a low pH (H_2O) of 4.0; with an organic matter content of 2.77 dag kg^{-1}, extractable nutrients of 75, 24, 0.75, and 15 mg kg^{-1} for Ca, Mg, P, and K, respectively, according to Coelho (1979).

Since clearing from forest in 1976, the fertilizer regime as shown in Table 1 had been carried out.

The climatological data for the 3-year period of this study is presented in Table 2 and these data are compared with the mean for the area.

Pasture Establishment

Davila-Calderon (1981) and Coelho (1979) have traced the history of establishment of the experimental pastures. They consisted of bahiagrass (Paspalum notatum Flugge) cv. Pensacola, seeded in 1977

Table 1. Dates and rates of fertlilizer applications.

Date	Calcitic limestone	Dolomitic limestone	N	P	K	Micro elements†
	kg ha^{-1}					
November 1976 to March 1978 (Coelho, 1979)	3400	3400	83.3	47.7	90.6	62.0
April 1979 April 1980 (Davila-Calderon, 1981)	-	-	-	15.5	59.6	36.0
April 1981 (Lopez, 1982)	-	-	-	23.1	89.0	8.0
May 1982 (Dzowela)	-	-	-	45.0	90.0	10.0

†Micro elements applied as FTE 503, a mixture containing 3% B, 3% Cu, 18% Fe, 7.5% Mn, 0.2% Mo, and 7% Zn.

Table 2. Climatological data at the Beef Research Unit.

	1980			1981			1982			Mean rainfall from 1970 to 1980
	Temperature			Temperature			Temperature			
	Max	Min	Rainfall	Max	Min	Rainfall	Max	Min	Rainfall	
	——°C ——		— mm —	—— °C ——		— mm —	——°C ——		— mm —	
Jan.	17.8	4.6	99.9	16.9	-2.0	22.3	19.2	2.9	163.5	99.9
Feb.	17.7	2.8	92.1	21.0	4.9	145.4	24.5	10.1	72.6	92.1
Mar.	22.3	10.7	110.0	22.6	5.2	97.5	24.9	10.1	127.5	101.0
Apr.	25.2	10.7	104.9	28.5	11.3	1.3	26.0	11.8	154.4	87.7
May	29.2	16.4	238.5	31.1	13.3	20.1	29.7	11.2	52.6	108.3
June	32.4	18.5	45.7	34.8	20.3	177.3	31.5	17.3	149.1	138.9
July	33.0	20.8	253.5	34.5	20.3	112.0	32.1	17.5	100.1	156.4
Aug.	33.5	20.9	140.7	32.3	20.5	183.1	32.2	16.9	75.7	173.2
Sept.	30.1	17.7	98.3	31.0	17.1	57.6	29.9	15.1	158.7	123.4
Oct.	27.3	12.5	40.6	28.1	12.1	39.1	27.5	13.0	39.4	47.5
Nov.	22.9	7.9	38.1	23.8	6.7	100.0	25.7	9.9	22.9	46.0
Dec.	20.7	2.8	12.9	20.5	3.4	54.6	22.6	8.8	33.8	75.0

at the rate of 28 kg ha^{-1} seed and the alleyways demarcating plots and pastures, respectively, were seeded to bahiagrass cv. Argentine. One-quarter of the area was seeded to Nolin's white clover (Trifolium repens L.) and an equal area was seeded to the Florida white clover selection that same year. These pastures were subjected to a grazing management for Coelho's Ph.D. dissertation research in 1978 and 1979.

The residual forage was mowed and removed after a thorough grazing subsequent to Coelho's experimental treatments in fall of 1979. Then, inoculated new white clover cv. Osceola was broadcast onto the entire area at the seeding rate of 2.5 kg ha^{-1}. A cultipacker was pulled over the field and pre- and post-seeding of the white clover. The nematocide-insecticide, Furadan® (a 10% carbofuran 2-3 dihydro, 2,2 dimethyl-7-7 benzofuranyl methylcarbamate) was finally applied to the entire field at the rate of 15 kg ha^{-1}.

The entire pasture was lightly grazed in the early spring of 1980, and in June it was cut to a uniform height and allowed a 40-day regrowth period before the treatments were introduced. For the next 2 years this grazing management system continued to be applied in early spring.

Experimental Design and Treatments

The experimental arrangement employed in this study was an incomplete factorial set with three experimental variables arranged in a split-plot design. The main plot pastures wre randomly assigned to the combinations of two variables of grazing pressures (GP) and period of deferment of grazing (PD). Thirteen combinations were selected according to a modified central composite design. These were four

factorial points, four axial points, one central point from the basic central composite design (Cochran and Cox, 1957), plus four extra corner points (Littell and Mott, 1974) as shown in Fig. 1. All the design points were replicated twice except for the four factorial points to give a total of 22 pastures (Table 3).

Three qualitative variables were applied to subplots within these pastures. Because of drainage differences, each pasture was divided into two blocks (one "wet" and the other "dry") with three subplots each. Each subplot measured 10 x 7 m and the whole pasture (main plot) was 50 x 10 m giving a total of 1.1 ha for the whole experimental area. All subplot treatments (T) were applied at random within each drainage block (Fig. 2). During the first year, three different treatments, herbicide, nematocide-insecticide, and control, were applied to the subplots. The herbicide, Banvel® (40.6% 3,6 dicloro-O-anisic acid) was intended to eliminate all white clover which would otherwise have been able to survive through summer. It was applied in June 1980, 1981, and 1982 at the rate of 2.3 L ha^{-1}. The nematocide-insecticide, Furadan® 10G was applied eight times at 28-day intervals from April to November, 1980 (Davila-Calderon, 1981). However, due to a lack of response in terms of white clover production that first year of application the Furadan® treatment was discontinued in subsequent years. Instead the study focussed on the residual effect from the 1980 Furadan® application in the subsequent years. In the control treatment no herbicide nor nematocide-insecticide was applied throughout the study period.

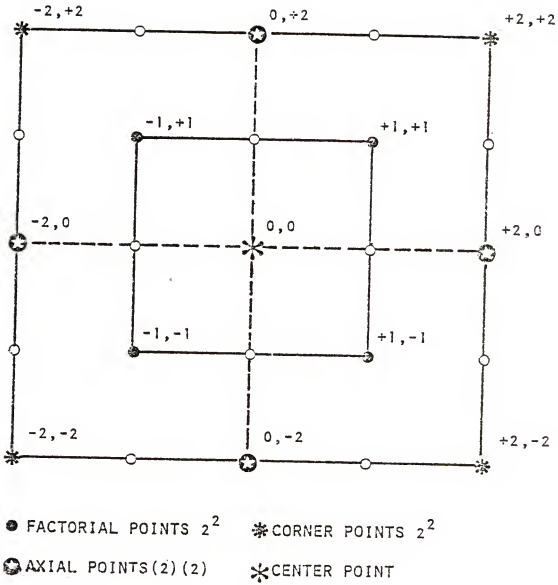


Fig. 1. Schematic representation of Design points based on a modified Central Composite Design.

Table 3. Treatment combinations applied to the main plots.

Period of deferment (X_1) (PD)		Target grazing pressure (X_2) (GP)	Pasture number	End of deferment (Date grazed)
Code	Days	kg ha^{-1}residue		
0	40	500	7	31 July
0	40	500	13	31 July
0	40	2500	6	31 July
0	40	2500	22	31 July
4	152	500	5	20 Nov.
4	152	500	10	20 Nov.
4	152	2500	11	20 Nov.
4	152	2500	17	20 Nov.
2	96	1500	12	25 Sept.
2	96	1500	19	25 Sept.
0	40	1500	3	31 July
0	40	1500	16	31 July
4	152	1500	4	20 Nov.
4	152	1500	15	20 Nov.
2	96	500	14	25 Sept.
2	96	500	21	25 Sept.
2	96	2500	1	25 Sept.
2	96	2500	20	25 Sept.
1	68	1000	18	28 Aug.
1	68	2000	9	28 Aug.
3	124	1000	2	23 Oct.
3	124	2000	8	23 Oct.

PASTURES	1	2	3	4	5	6
1	●-W	▲-W	■-D	▲-W	■-D	●-D
2	■-W	▲-W	●-W	●-D	■-D	▲-D
3	▲-W	●-W	■-D	●-D	▲-W	■-D
4	●-D	▲-D	■-W	●-W	▲-W	■-D
5	■-D	●-W	▲-D	■-W	▲-W	●-D
6	▲-W	■-W	▲-D	●-W	■-D	●-D
7	●-W	▲-W	■-W	■-D	▲-D	●-D
8	■-W	●-W	▲-W	▲-D	●-D	■-D
9	▲-W	■-W	●-W	■-D	▲-D	●-D
10	■-W	●-W	▲-W	●-D	■-D	▲-D
11	●-W	■-W	▲-W	●-D	■-D	▲-D
12	▲-W	●-W	■-W	●-D	■-D	▲-D
13	●-W	■-W	▲-W	●-D	■-D	▲-D
14	■-W	▲-W	●-W	▲-D	●-D	■-D
15	▲-W	●-W	■-W	▲-D	■-D	●-D
16	▲-W	■-W	●-W	●-D	■-D	●-D
17	▲-W	■-W	●-W	▲-D	■-D	●-D
18	■-W	●-W	▲-W	■-D	●-D	▲-D
19	■-W	▲-W	●-W	▲-D	●-D	■-D
20	●-D	▲-W	▲-D	■-D	●-W	■-W
21	■-D	▲-D	●-D	▲-W	●-W	■-W
22	▲-D	■-D	●-D	●-W	▲-W	■-W

SUBPLOTS

W Wet block D Dry block

■ Control ● Banvel® ▲ Furadan®

Fig. 2. Scheme of the treatments as applied to the subplots.

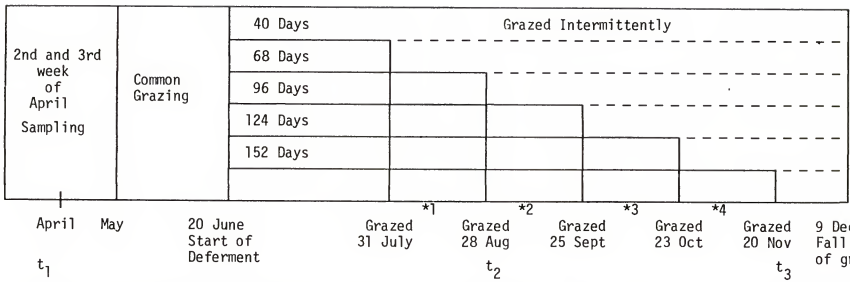
Grazing Management

The system of mob or common grazing management as described by Shaw et al. (1976) was applied to the pastures in order to achieve the targeted grazing pressure (as kg residual forage dry matter ha^{-1}). Deferment periods were in units of 28 days from 31 July to 20 November in all years. Between two to ten Brangus heifers weighing 300 to 350 kg were used to graze the pasture to the target grazing pressure. The number of days spent grazing varied with the amount of forage on offer and the required grazing pressure. Two to 7 days were adequate in most cases. Grazing continued periodically to maintain the prescribed grazing pressure after each deferment period. No grazing took place from the first week of December until the third week in April. The animals were kept on Limpograss (Hemarthria altissima) and bahiagrass reserve pastures between grazings of the experimental plots. No measurements were made on the animals, as a result they were assigned to the experimental pastures without randomization. The grazing scheme employed in the study is presented in Fig. 3.

Measurements and Recordings

Total Available Forage Dry Matter

During the experimental period a non-destructive double-sampling procedure was used to estimate the amount of forage (Mannetje, 1978) as had Davila-Calderon (1981) and Lopez-Nunez (1982). A simple disk meter of 0.50 m^2 (Santillan et al., 1979) was used to determine the height of the sampled pasture after the disk was dropped from a 1



*1 - *4 = Dates 10 August, 10 September, 10 October, and 10 November, when exclosure cages were introduced to prevent subsequent grazings.

- - - - = Grazed intermittently to the appropriate pressures afted end of period of deferment.

t_1 = Time for sampling for total available forage, white clover forage, weed cover, white clover cover, disease and pest attack in 1982 and 1983.

t_2 = Sampling for soil seed reserves in 1982.

t_3 = Estimate of amounts of seedling recruitment and live-over clover plants in 1982.

Fig. 3. Grazing and sampling scheme employed during the experiment.

meter height above ground. The plant material under the disk was then harvested as close to the soil surface as possible using rechargeable hand shearers. This harvest was done in April 1982 and 1983. The plant material under the disk was oven-dried for at least 48 hours at 65°C. A linear function that relates the compressed height (X_1) to dry matter production (Y_1) was calculated (Table 4). The linear functions were used to convert all disk meter readings to dry matter forage yield.

White Clover Forage

Percent white clover forage was estimated visually in April 1982 and 1983. A linear function estimating visual percent white clover forage (X_2) to the actual percent dry matter white clover based on hand separation of the harvested forage (Y_2) was derived in April 1982 and 1983, according to Hunt (1964). The relationship between the visually appraised and actual percent clover contents is shown in Table 5. This relationship was used to convert all visual estimates to actual clover yields. Also the response variable, percent clover ground cover, was visually estimated in relation to the overall cover of the pasture components. This procedure was applied also for the estimate of percent cool season weed cover in April 1983.

Table 4. Relationship between disk meter readings (X_1) and dry matter ha^{-1} (Y_1).

Time	n	$b(X_1)$	$s_{y \cdot x}$*	Y_1	R^2	cv
		$kg\ ha^{-1}cm^{-1}$	$kg\ ha^{-1}$	$kg\ ha^{-1}$		%
April 1982	20	331	664	2692	0.95	24.67
April 1983	28	291	358	3276	0.99	10.91

*Standard error of the estimate.

Table 5. Relationship between visual (X_2) and actual estimates of percent white clover (Y_2) on a DM basis.

Time	n	$b(X_2)$	$s_{y \cdot x_2}$*	$\bar{Y}_2$	R^2	C.V.
April 1982	28	0.512	8.20	24.51	0.93	33.46
April 1983	27	0.845	9.31	48.01	0.97	19.38

*Standard error of the estimate.

Survival Potential of White Clover

Soil Seed Reserves

The number of white clover seed in the soil under the pasture canopy was assessed in mid August. Three cup cutter soil core samples measuring 6.5 cm deep and 5.8 cm in diameter were taken per subplot at random. The core soil samples from each subplot were bulked and air-dried under room temperature conditions. The air dry soil was arranged in germination flats, wetter with water, and the flats were set at sub-zero temperatures in refrigerators to simulate a cold treatment for 48 hrs. The hard-frozen flats were set out under a mist auto-waterer for a germination test. At the end of the first 21-day period all germinated clover seedlings were removed from the flats and recorded. The flats were subsequently given the 48-hour freeze treatment again at the end of the first and second 21-day periods and the amounts of germinating seedlings recorded at the end of these germination periods. The germination records gave an indication of the total number of seeds as well as an indication of readily germinable (1st 21-day period), moderately soft (2nd 21-day period), and hard seed components (3rd 21-day period), all reported on a m^2 basis.

White Clover Plants Living Through Summer/Fall

At the end of the last deferment period in the third week of November, a count was made of the number of white clover plants (stolons) appearing to have survived through summer from the preceeding spring. Three meter square quadrats were consistently taken

diagonally across the subplots. For the purpose of this count a stolon was taken to have survived if it was well rooted, had at least two leaves and was equal or longer than 3 cm.

Recruited White Clover Seedlings

Also at the end of the last deferment period, the number of recruited seedlings was recorded. Nine 20-cm^2 quadrats were consistently taken diagonally across the subplots. The number of white clover seedlings (two cotyledons plus a true trifoliate leaf) were recorded from each of the 20 cm^2 quadrat and the average number expressed on a m^2 basis.

Disease and Pest Attack

Root and Stolon Rot Disease Monitor

Some time in summer (July) at the peak of humid weather, there was an outbreak of root and stolon rot disease caused by *Pythium* and *Fusarium* species. The severity of disease attack was quantified by scores on the 0-5 scale in increasing order of severity, visually appraised. Samples of diseased stolons were submitted for identification by the Plant Pathology Department of the Institute of Food and Agricultural Services, University of Florida.

Other Diseases and Pests

Other diseases of significance and pests were monitored to assess their influence on clover survival ability. In April (1983) leaf rust (*Uromyces trifolii*) var *trifoli repentis* (Liro) Arth.

and Phoma leafspots (Phoma sp.) attacks were scored, also on a 0-5 scale. This was done for leaf weevil attacks as well, at this time. Counts of grazer snails (Polygyra cereolus Muhlfeld) were made during the spring-summer period using 20 m^2 quadrats. Eighteen random quadrats (three per subplot) were taken. All counts were made between 11.00 and 14.00 hours to minimize the effects of diurnal movements of the snails between the soil and forage (Dietrick, 1961).

Soil Moisture

In order to account for within-site difference in soil moisture, soil samples were taken early in spring-summer, 1982, at 2-week intervals. These soil samples were used for gravimetric determination of soil moisture. Soil samples were collected using a core sampler to 20-22.5 cm depth.

Total Non-Structural Carbohydrates and Crude Protein

White clover rooted stolons were dug from the pasture in April; there were washed immediately in running tap water. They were dried for 45 min in a 120°C preheated forced hot air oven at 100-105°C. This temperature denatured enzymes to arrest respiratory losses of TNC. After the preliminary 45 min drying, the samples were then dried at 70°C for a period of at least 48 hrs.

Stolons, with roots, but without leaves were ground first through a Wiley mill to pass a 4-mm screen and then through a U.D. Cyclone mill to pass a 0.5 mm or a 40-mesh screen. Ground samples were analyzed for TNC, using the Christiansen et al. (1982) procedure.

The ground samples, weighed to 0.100 to 0.1099 g were placed into 25 ml Erlenmeyer flasks and heated in a boiling water bath with 5 mL of distilled or deionized water for 10 min to gelatinize the starch. Five milliliters of 0.2M acetate buffer (pH 4.8) were added to bring the volume to 10 mL. One milliliter of an enzyme mixture was placed in each flask to digest the weighed sample. The enzyme mixture consisted of 2.5 mL invertase concentrate in glycerol; 1.25 g amyloglucosidase; 0.1 g thymol; 45 mL distilled water, and 5.0 mL 0.1M acetate buffer. The thymol was used to prevent microbial growth during incubation. After the enzyme addition the samples were incubated at 37°C for 48 hrs.

Following incubation, aliquot volumes for determination of the Beer's Law relationship were made. This volume contained 1 mL of the sample preparation to which were added 7 mL of distilled water plus 1 mL of each of alkaline reagent and the color forming arsenomolybdate reagent. A regression equation was derived to establish the relationship between sugar content of the sample and the optical density read at 540 nm on the Coleman JR II Spectrophotometer.

For N percentage analysis the standard micro-Kjeldahl procedure was used. Crude protein was obtained conventionally by multiplying total N by the factor of 6.25 and results expressed on dry matter basis. Total N was determined based on Schuman et al. (1973) using the following modifications: a 0.1 g dried and ground sample (to pass through 1-mm screen) was placed in each digestion test tube together with 3.20 g of prepared catalyst (90% anhydrous K_2SO_4 10% anhydrous $CuSO_4$), 2 or 3 Alundum boiling chips and 10 mL concentrated H_2SO_4. The

contents were mixed in a vortex and a total of 2 mL of 30% H_2O_2 were carefully added in 0.5, 0.5, and 1 mL increments. The samples were allowed to stand until reaction of H_2O_2 ceased, then the samples were digested at 375 C for 3 hrs after which they were diluted, brought to 75 mL volume, and the N concentration read in the Auto Analyzer. The percent N was calculated using the following equation:

$$\% N = 0.0075 \frac{\text{low ppm} \left(\frac{\text{high ppm - low ppm}}{\text{high dens - low dens}}\right)(\text{Sample dens - low dens})}{\text{Sample weight}}$$

Early Animal Exclusion Cages

Just over a week following the first grazing at the end of periods of deferment, exclusion cages measuring nearly 1.5 m in diameter were introduced in some parts of the pasture in which a complete grass-clover sward was observed. Two cages were introduced per pasture. These cages excluded access by the grazing cows to these parts of the pasture for the remainder of the summer-fall season, from the dates shown (*1 to *4) in Fig. 2. In April of the following spring, forage in these cages and sites outside these cages, selected at random were compared with respect to total available forage, white clover forage, disease attack scores, and pest attack scores.

Statistical Analysis

The General Linear Models (GLM) procedure was used for analyses of variance (Helwig and Council, 1979). Deferment period (DP) and grazing pressure (GP), their quadratic functions, and cross-products were used as independent variables for all the dependent variables in the main plots, i.e., total forage yield, white clover yield, percent white clover ground cover, number of perennating clover plants, number

of white clover seedlings recruited, disease and pest attack scores, and percent weeds ground cover. Since the experiment had two experimental variables primarily (discounting the two subplot treatments) set on the central composite design, the results of the analysis of variance were used in plotting three-dimensional response surfaces of the predicted values. This employed the response surface methodology (Balaam, 1975; Mott, 1982) using the G3D procedure (Council and Helwig, 1981). Separate analyses were made for the response variables of the subplot treatments (Block, i.e., wet vs dry site, and the herbicide treatments). The models used in these computer analyses were:

(a) For the main treatments:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_1^2 + \beta_3 x_2 + \beta_4 x_2^2 + \beta_5 x_1 x_2 + \varepsilon$$

where Y = the response (dependent) variable,

β_0= overall mean response,

β_1 and β_2 = the response associated with linear and quadratic terms of the independent variable, x_1, respectively,

β_3 and β_4 = the response associated with linear and quadratic terms of the independent variable, x_2, respectively,

β_5= the response associated with the interaction of the independent variables x_1 and x_2,

ε = random (residual) error.

(b) With subtreatments included:

$$Y = \beta_0 + \beta_1 \text{ site} + \beta_2 T + \beta_3 PD + \beta_4 GP + \beta_5 \text{site*}T + \beta_6 \text{site*}PD + \beta_7 \text{site*}GP + \beta_8 T\text{*}PD + \beta_9 T\text{*}GP + \beta_{10} \text{site*}PD\text{*}GP + \beta_{11} T\text{*}PD\text{*}GP + \varepsilon$$

where Y = the response (dependent) variable,

β_0= overall mean response,

β_1 to β_4 = the responses associated with the independent variables, site, T, PD, and GP, respectively,

β_5 to β_7 = the responses associated with the interaction of the independent variable, site with T, PD, and GP, respectively,

β_8 and β_9 = the responses associated with the interaction of the independent variable, T with PD and GP, respectively,

β_{10} = the response associated with the interaction between the independent variables, site, PD, and GP,

β_{11} = the response associated with the interaction between the independent variables, T, PD, and GP,

ε = random (residual) error.

CHAPTER IV
RESULTS AND DISCUSSION

Soil Moisture Differences on the Site

The experimental design in this study took into account the fact that there were major differences between the "dry" and "wet" sites within the experimental area. Of all pastures, only in the middle section of the area constituting pastures 9, 11, 12, 13, 14, 15, 16, 17, and 18 were there significant differences between the wet and dry sites in early spring (Table 6). Other pastures such as 3, 4, 5, and 6 were equally wet, but there was no major gradient change to show a drastic difference in soil moisture bewteen the dry and wet sites.

In those pastures that showed a significant change in moisture content between sites, a high water table that resulted in ponding was not uncommon during the months July-September (USDA, 1982). Those pastures with soil moisture values below 20.0 day kg^{-1} were mostly well-drained during much of the year, and the plants growing on them showed extreme moisture stress, especially in the months of insufficient precipitation, such as May 1982 (Table 2).

Total Available Spring Forage

The total available forage values in spring (April 1982 and 1983) are shown in Figs. 4, 5, 6, and 7. The response in 1982 was a characteristic maximum point that rose towards the heaviest grazing

Table 6. Within pasture differences in soil moisture in spring between "wet" and "dry" (concentration on soil dry matter basis).

Pasture	"Wet" block	"Dry" block	Means
	moisture on soil dry matter basis dag kg^{-1}		
1	19.1 a*	19.1 a	19.1
2	19.1 a	18.7 a	18.9
3	25.2 a	22.9 a	24.1
4	26.0 a	24.9 a	25.4
5	21.4 a	20.7 a	21.1
6	24.5 a	24.7 a	24.6
7	23.0 a	19.5 a	21.3
8	23.4 a	20.9 a	22.2
9	26.3 a	16.8 b	21.6
10	25.8 a	20.2 a	23.0
11	24.2 a	19.7 b	22.1
12	26.4 a	20.8 b	23.6
13	22.6 a	18.3 b	20.4
14	24.4 a	20.7 b	22.5
15	26.6 a	18.4 b	22.5
16	22.1 a	17.8 b	19.9
17	22.5 a	15.9 b	19.2
18	22.6 a	15.5 b	19.1
19	20.2 a	19.0 a	19.6
20	21.9 a	19.3 a	20.6
21	16.3 a	14.8 a	15.5
22	19.3 a	16.2 a	17.7
Means	22.9	19.3	

*Values within the row followed by the same letter are not statistically different.

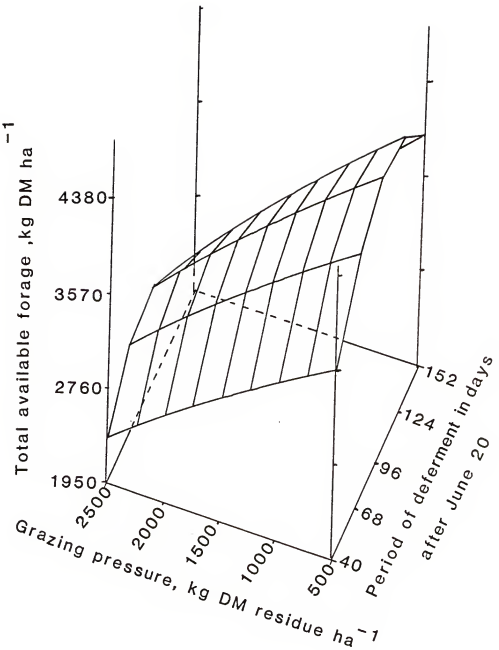


Fig. 4. Surface plot of total available spring forage in response to period of deferment and grazing pressure for April 1982.

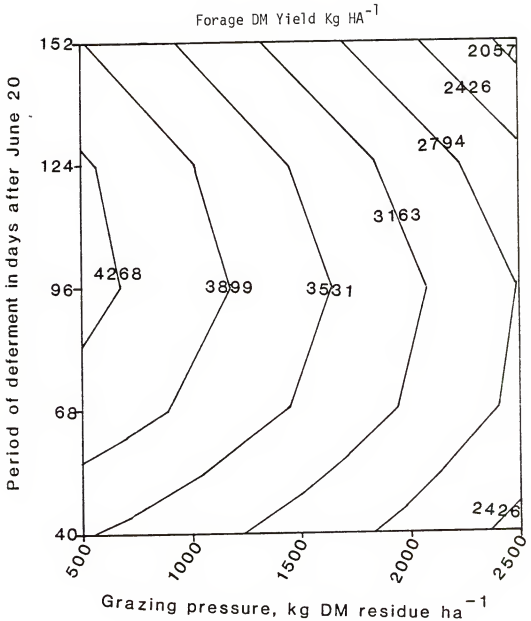


Fig. 5. Contour plot of total available spring forage in response to period of deferment and grazing pressure for April 1982.

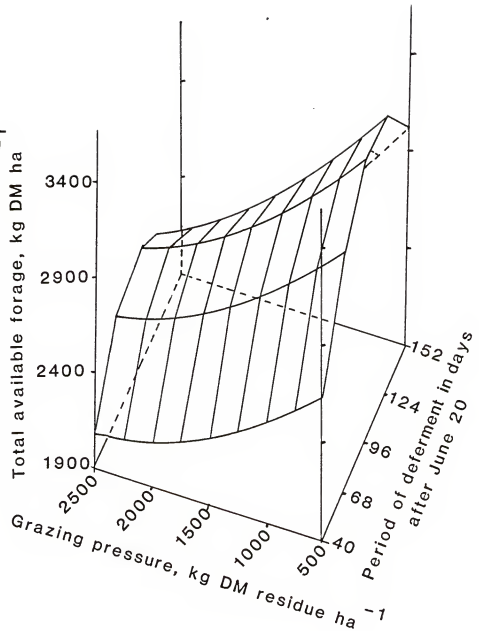


Fig. 6. Surface plot of total available spring forage in response to period of deferment and grazing pressure for April 1983.

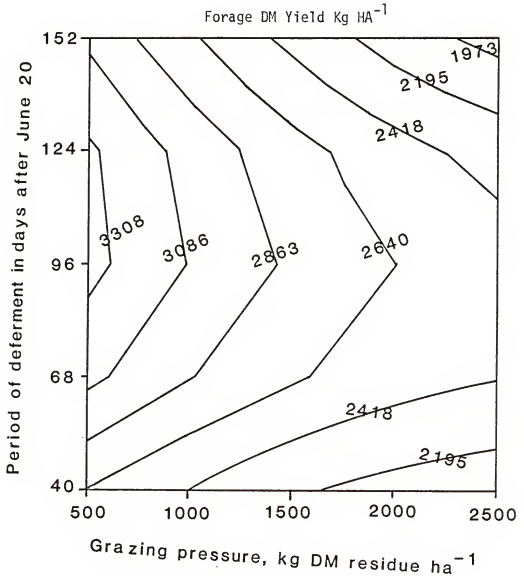


Fig. 7. Contour plot of total available spring forage in response to period of deferment and grazing pressure for April 1983.

pressure (least amount of post-grazing residue ha^{-1}). That for 1983 was a typical saddle point also rising towards the heaviest grazing pressure. The highest amounts of available forage were obtained at the 500 kg DM ha^{-1} level of grazing pressure (Figs. 5 and 7). In each year, forage reached a maximum at the 96-124 days period of deferment, but there was no effect of period of deferment (P = 0.9307 and 0.5395, respectively, for 1982 and 1983). There was a quadratic effect of period of deferment (PD^2) (P = 0.0009) in both years. Grazing pressure gave a linear response in both years (P = 0.0001 and 0.0001, respectively). However, the quadratic effect (GP^2) was not significant. There was also no interaction (PD x GP) (P = 0.1178) as shown in Appendix Tables 15 and 17.

Within the main plots, the wetter site gave a high (P = 0.0115) total available forage (Table 7; Appendis Tables 16 and 18). The increase in total available forage over the drier stie was 11 and 13%, respectively, for 1982 and 1983. The subplots that received the herbicide, Banvel® consistently gave the smallest amount of forage in both years. Predominantly composed of seedling (volunteer) white clover, these subplots did not have a fully-developed clover stand to contribute effectively to total available forage. On the other hand, the increased forage advantage of the Furadan® subplots may not be ascribed to the residual effect of the nematocide-insecticide application, other than the fact that it (Furadan® application) and the control subplots contained a good proportion of perennating clover in the stand. The increased forage advantage with the heaviest grazing pressure and intermediate periods of deferment appears to correspond with a better

Table 7. Total available and white clover forage (kg DM ha^{-1}) on wet and dry sites and on herbicide treated subplots.

Forage yield	Year					
	1982			1983		
	oven-dry herbage, kg ha^{-1}					
	Between site					
	Wet		Dry	Wet		Dry
Total available forage	3770 a*		3400 b	2730 a		2410 b
White clover forage	910 a		860 a	1120 a		1000 a
	Between herbicide treatments					
	Control	Banvel	Furadan	Control	Banvel	Furadan
Total available forage	3480 b	3320 b	3960 a	2550 ab	2320 b	2840 a
White clover forage	940 a	640 b	1070 a	1090 ab	900 b	1200 a

*Values within the row and year that are followed by the same letter are not statistically di-ferent at P = 0.05 level.

survival potential and a more effective contribution to total available forage by the white clover component. This grazing management combination resulted in the highest white clover contribution to total available forage, i.e., 32 vs 19% and 46 vs 34% between this management combination and the more lax grazing management, respectively, for 1982 and 1983, respectively. There was also a better white clover contribution towards total available forage on the wetter than drier sites, again because of a better clover survival potential.

White Clover Spring Forage

As total available forage, white clover forage response was a typical maximum point (1982) and a saddle point (1983). The increased forage advantage of the heaviest grazing pressure and the intermediate periods of deferment (68 to 96 days) was apparent in both years (Figs. 8, 9, 10, and 11). For each year the responses to period of deferment ($P = 0.0001$ and 0.0011, respectively) and grazing pressure ($P = 0.0001$ and 0.0001, respectively) were linear as shown in Appendix Tables 19 and 21. There was also a quadratic relationship to period of deferment ($P = 0.0001$ and $P = 0.0009$, respectively) but GP^2 and interaction (PD x GP) were not significant ($P > 0.05$).

The white clover forage difference between the wet and dry sites was not significant (Table 8; Appendix Tables 20 and 22), but the Banvel® application resulted in significantly lower white clover forage. Here white clover forage too showed to be favored by the best survival potential that occurred at the combination of heavy grazing pressure and intermediate periods of deferment. It showed a positively

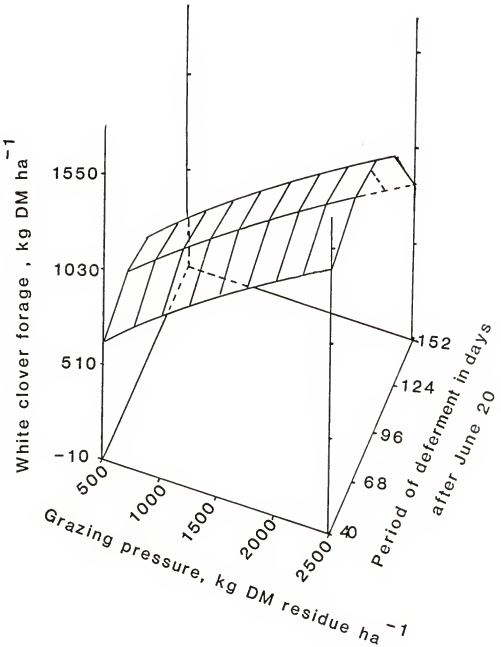


Fig. 8. Surface plot of white clover spring forage in response to period of deferment and grazing pressure for April 1982.

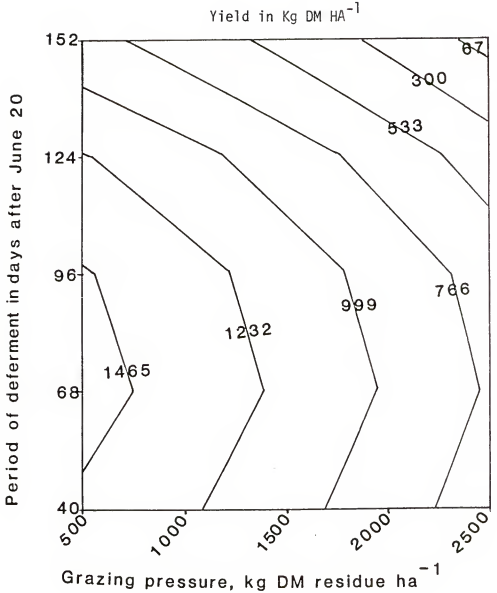


Fig. 9. Contour plot of white clover spring forage in response to period of deferment and grazing pressure for April 1982.

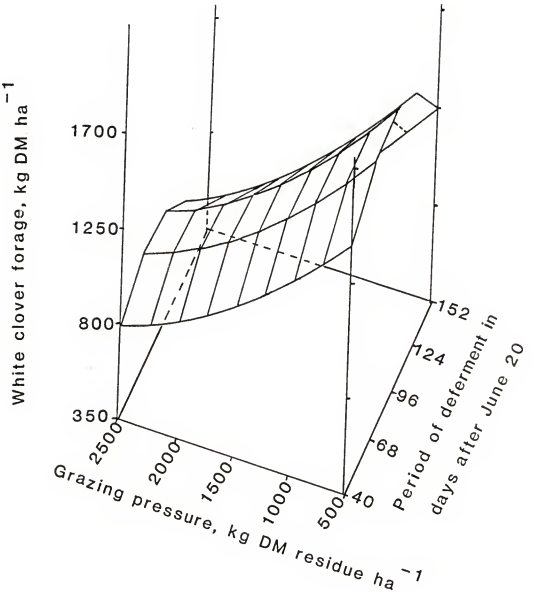


Fig. 10. Surface plot of white clover spring forage in response to period of deferment and grazing pressure for April 1983.

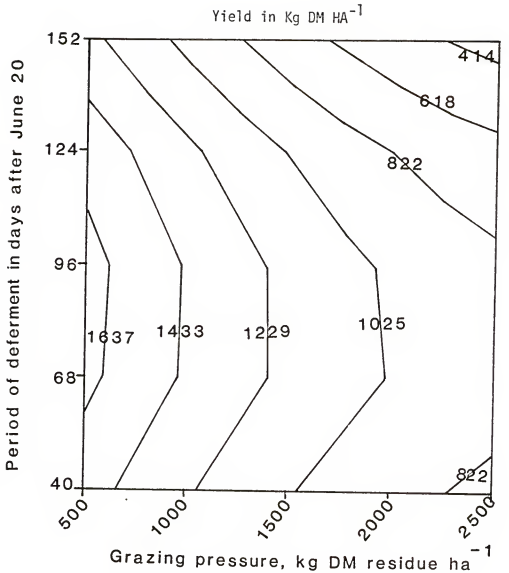


Fig. 11. Contour plot of white clover spring forage in response to period of deferment and grazing pressure for April 1983.

Table 8. Number of white clover plants perennating and seedlings recruited m^{-2} on wet and dry sites and herbicide treated subplots.

Parameter	1982		
	No. m^{-2}		
	Between sites		
	Wet		Dry
White clover perennating plants m^{-2}	6.78 a*		4.94 a
Recruited white clover seedlings m^{-2}	395.00 a		330.00 a
	Between herbicide treatments		
	Control	Banvel	Furadan
White clover perennating plants m^{-2}	7.87 a	1.12 b	8.58 a
Recruited white clover seedlings m^{-2}	351.00 a	291.00 a	445.00 a

*Values within the row followed by the same letter are not statistically different at P = 0.05 level.

significant correlation with those factors which survival ability depends upon. For the purpose of this study these are the amount of annual seedlings recruitment, white clover soil seed reserves, white clover ground cover, and number of live-over clover plants through summer-fall (Table 9). The low correlation with live-over clover plants is explained by the very low numbers of plants recorded (15 plants m^{-2}).

Increased white clover yields under more intensive and frequent grazing management have been reported many times before (Schlundt, 1977; Andrade, 1979; Brougham, 1959; Blaser and Killinger, 1950). The reduced grass competition as a result of a more open residue may explain the more rapid growth of white clover under this management during winter and early spring resulting in higher yields and denser stand. Cameron (1969) found that the rate of clover growth was severely reduced in lightly grazed pastures based on Paspalum sp. On removal of the competitive vegetation and reduced post-grazing residue, white clover growth rates and yield were reported to be increased by Turkington et al. (1979) and Murtagh (1977).

Survival Potential of White Clover

Soil Seed Reserves

Several factors are known to determine the quantity and quality of soil seed reserves. These, according to Thurston (1960), Barton (1962), and Iverson and Wali (1982) are:

Table 9. Linear correlation coefficients and probability levels of white clover yield with soil seed reserves, recruited white clover seedlings, white clover percent ground cover, live-over clover plants.

Dependent variable	Independent variables			
	White clover soil seed reserves m^{-2}, Aug. 1982	White clover recruited seedlings m^{-2}, Nov. 1982	Percent white clover ground cover, Apr. 1983	No. white clover live-over plants m^{-2}, Nov. 1982
White clover spring forage yield, kg DM ha^{-1}, April 1983	r^2 = 0.55	r^2 = 0.73	r^2 = 0.83	r^2 = 0.30
	PROB>/R/=0.0085*	PROB>/R/=0.0001	PROB>/R/=0.0001	PROB>/R/=0.1775

*PROB>/R/values 0.05 are stastically significant.

(a) reproductive potential of plants (seed heads m^{-2} x seeds $head^{-1}$ less annual emergence),

(b) dispersal mechanisms,

(c) dormancy patterns,

(d) characteristics of the soil,

(e) biotic influences, i.e., predation and decomposition caused by fungal and/or bacterial diseases,

(f) weather fluctuations, and

(g) disturbances to the soil surface (such as caused by puddling and compaction by hoofs or grazing animals).

Disrupting the soil surface, such as by trampling and puddling by hoofs of grazing animals and removal of the thick thatch by heavy grazing pressure often breaks dormancy by exposing seeds to unfiltered light, fluctuating temperatures, and reduced CO_2 concentration (Bazzar, 1970, 1979). The significance of these factors in the present study is quite apparent. A combination of heavy grazing pressure (least residue) and short period of deferment (40-68 days) resulted in largest amount (3000 seeds m^{-2}) of white clover soil seed reserves (Fig. 12). There was only about 1/3 the amount of soil seeds at the longest period of deferment and about 1/2 that amount at the lightest grazing pressure (Fig. 13). This was no doubt the result of the less open pasture residue at this grazing management which in turn resulted in more dormant soil seed reserves which germinated less readily (Figs. 14 and 15). A close and more frequent grazing management has been known to induce increased seed production in T. repens (Haggar et al., 1963). Heavy grazing pressure of grass-clover associations results in reasonably high yield of clover seed.

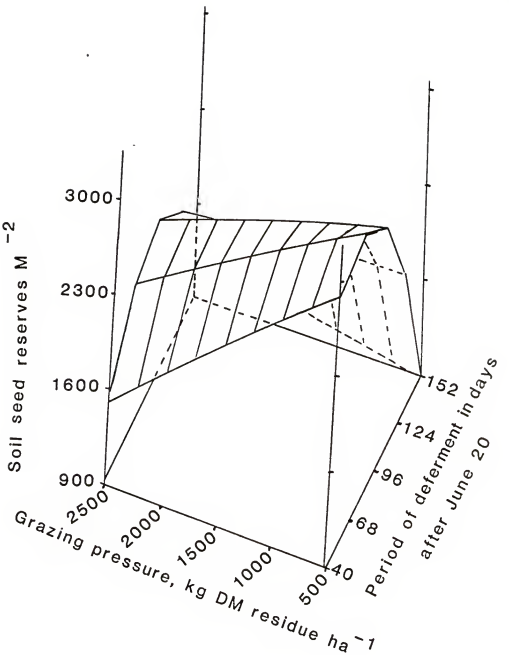


Fig. 12. Surface plot of white clover soil seed reserves in response to period of deferment and grazing pressure.

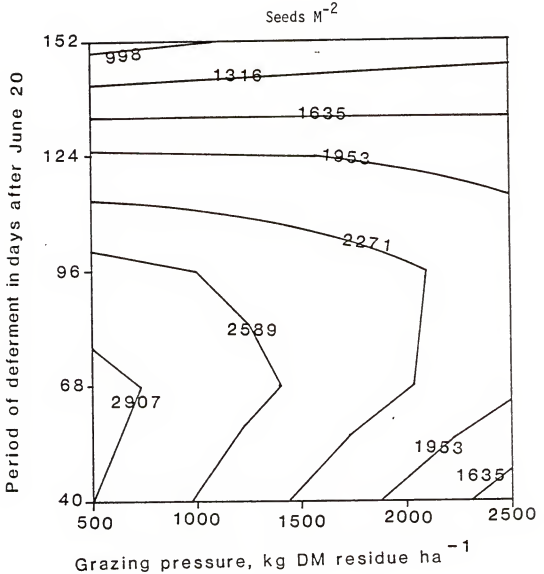


Fig. 13. Contour plot of white clover soil seed reserves in response to period of deferment and grazing pressure (No. of seeds m^{-2}).

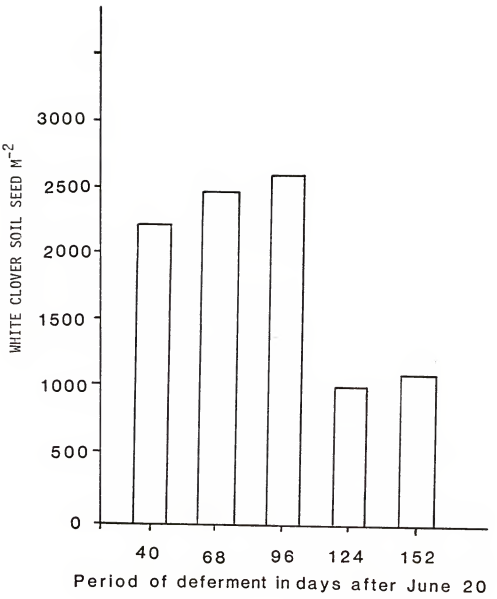


Fig. 14. Number of white clover soil seeds m^{-2} in response to period of deferment.

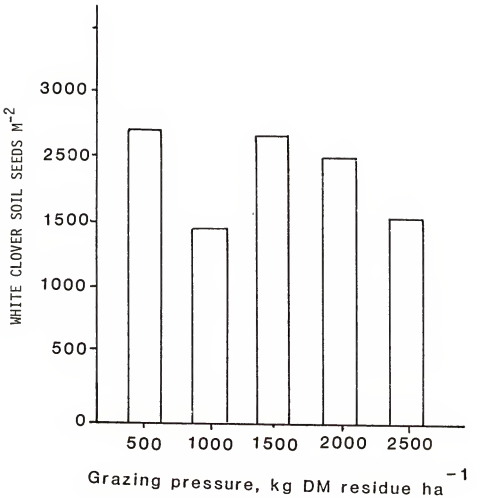


Fig. 15. Number of white clover soil seeds m^{-2} in response to grazing pressure.

The reason for this is that shading from companion vegetation residue is minimal during the spring flush of herbage growth, so that light is able to penetrate to the clover stolons and flower initiation is not inhibited. Furthermore, close defoliation in the late summer-autumn period encourages vigorous stolon branching so that the number of flower sites the following spring at which flower buds can be initiated is increased (Zaleski, 1964).

The white clover seed reserves recovered from this study appear reasonably adequate (up to 3000 m^{-2}) when compared, for instance, with reports by Jones and Evans (1977), Jones (1981, 1982). However, they fell far below the seed quantities reported from pasture systems in New Zealand, with a range of 9300 to 50,000 m^{-2} (Suckling, 1950; Hyde and Suckling, 1953). These data reported in the current study only cover recoveries from a germination count of seedlings. It is likely that this recovery procedure underestimated the actual amounts of seed. For instance, no account was made of the ungerminated hard seeds which could not be recovered. Furthermore, the soil seed reserves recovered by the procedure in this study may not directly reflect the current year's legume seed yield. Seed in the soil under a mixed pasture have been shown (Jones and Evans, 1977) to be not directly related to current legume seed yield. In most cases, the seed reserves are substantially greater, because legume seeds are able to persist in the soil. Various Trifolium species owe their persistence to varying proportions and amounts of hard and soft seed (Hodgkinson and Williams, 1979). What is important, nevertheless, is the fact that there were adequate seed reserves in the soil for the continued survival of

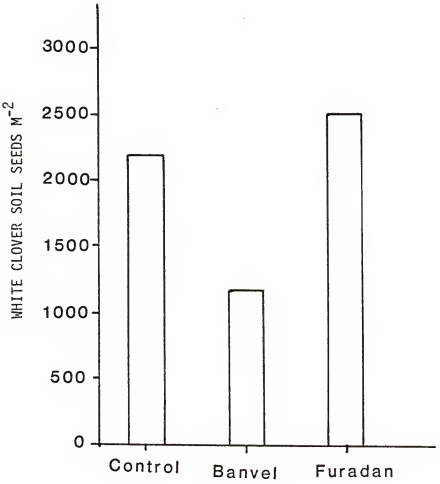


Fig. 16. Number of white clover soil seeds m^{-2} in response to herbicide treatments.

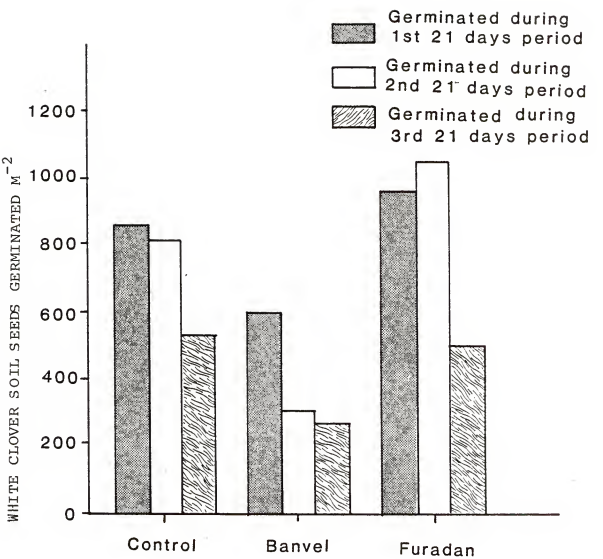


Fig. 17. White clover soil seed germination budget in response to herbicide treatments (No. of seedlings germinated m^{-2}).

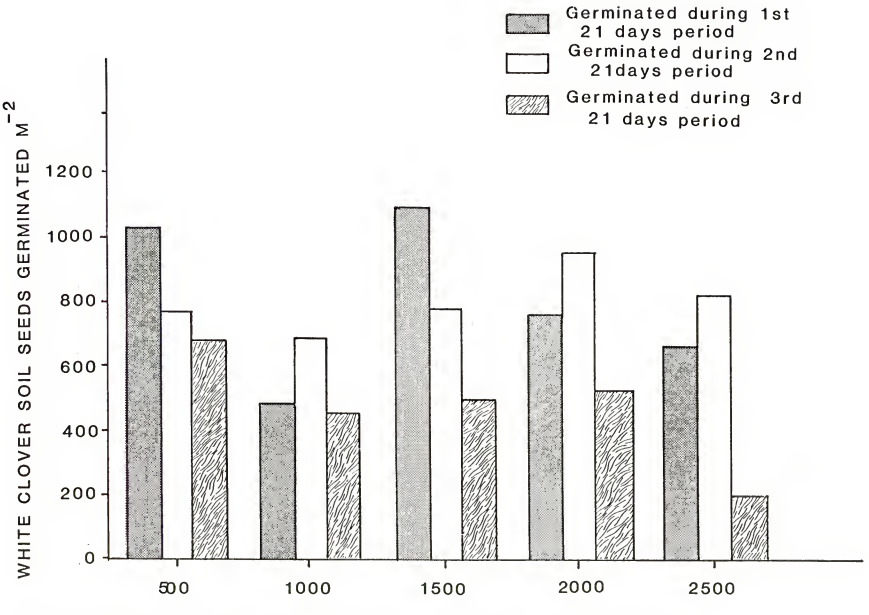


Fig. 18. White clover soil seed germination budget in response to grazing pressure.

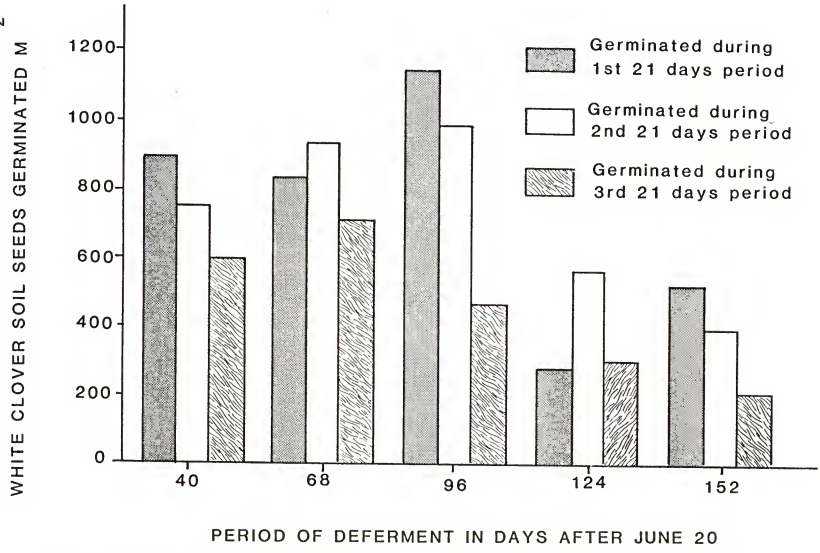


Fig. 19. White clover soil seed germination budget in response to period of deferment.

white clover stands from one spring to the other. Where clover stands had been deliberately eliminated by Banvel®, the amount of seed potentially able to revegetate the pasture amounted approximately to one-half of those in the subplots without the herbicide applied (Fig. 16).

Nearly two-thirds of the seed reserves were readily able to germinate by the second germination period. This means that about one-third of the seed reserves was the hard-to-germinate component under all managements (Figs. 17, 18, and 19). Proportions varied according to the absolute soil seed reserves.

Contrary to Jones' (1982) findings in which largest soil seed reserves were recorded on wetter than on drier sites, in the current study, the correlation between soil moisture content (wet vs dry) and soil seed reserves was negative and not significant (r^2 = -0.55 and PROB>/R/ = 0.1798). One logical explanation for this could have been the unfavorably wet (ponding) conditions that probably resulted in seed rotting on this site.

Number of Perennating White Clover Plants

Number of white clover plants perennating through summer from the preceeding spring was affected by period of deferment (Table 23) (P = 0.0001). At the longest period of deferment there were few white clover plants surviving through the summer (Figs. 20 and 21). Maximum number of plants was at the combination of the shortest period of deferment and the intermediate grazing pressures (1000-1500 kg DM residue ha^{-1}). This is in agreement with Taylor and Rossiter (1974) work in which the

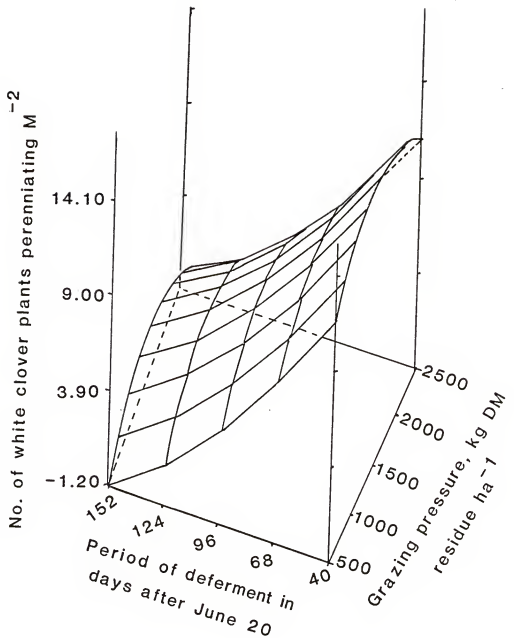


Fig. 20. Surface plot of number of white clover plants perennating through summer-fall in response to period of deferment and grazing pressure.

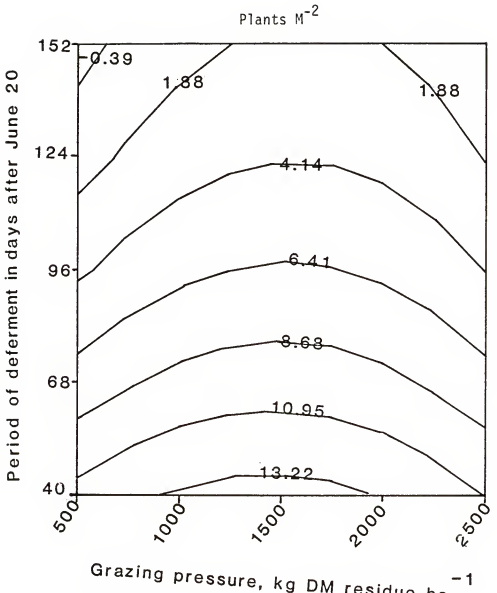


Fig. 21. Contour plot of number of white clover plants perennating through summer/fall in response to period of deferment and grazing pressure (No. of plants m^{-2}).

longevity of T. subterraneum and T. hirtum in lightly and infrequently grazed and ungrazed mixed swards was very poor. Competition for light especially from the thick forage seems to be implicated.

There were slightly more perenniating white clover plants on wetter than drier sites. Only about one-eighth of the plants survived in the subplots that received the herbicide Banvel® compared to those without application (Table 9; Appendix Tables 23 and 24). This was expected, the Banvel® application was meant deliberately to eliminate all white clover that might have survived.

Number of White Clover Seedlings Recruited

The number of white clover seedlings recruited m^{-2} was affected by both period of deferment and grazing pressure (P = 0.0001 and 0.0001, respectively). The quadratic terms (PD^2 and GP^2) were not significant, but there was an interaction (PD x GP) (P = 0.0012) as shown in Appendix Tables 25 and 26. The highest number of white clover seedlings was at the combination of shortest period of deferment and heaviest grazing pressure (Figs. 22 and 23). The main seedling emergence in the pastures was in the early October period, when screen temperatures had reached below 28°/15°C (Table 2). This could be accounted for by the low temperature requirement for fluctuating temperatures to soften hard seed. Any grazing management practice, such as heavy and short periods of deferment increases soil temperature fluctuations, also leads to lower soil minimum temperature, thus meeting both requirements. Pastures not grazed by this date (i.e., 124 and 152 days periods of deferment), and lightly grazed pastures

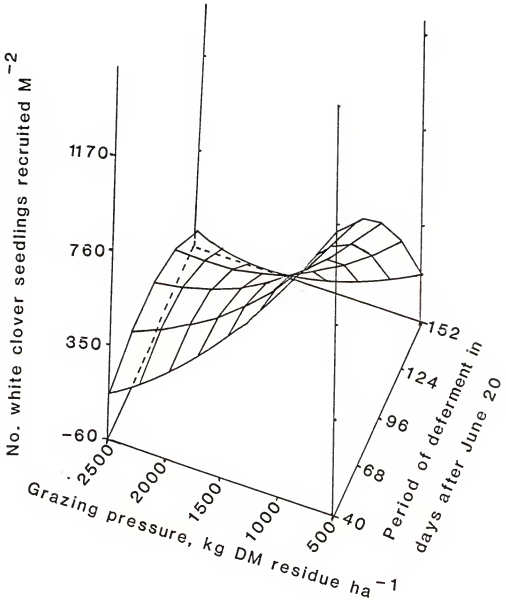


Fig. 22. Surface plot of white clover seedlings recruited in response to period of deferment and grazing pressure.

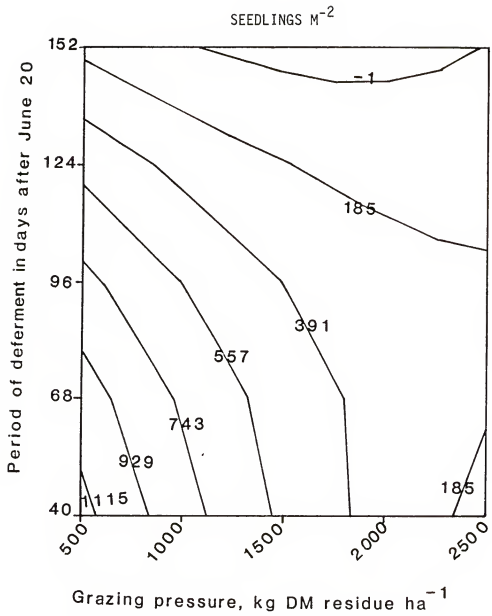


Fig. 23. Contour plot of white clover seedlings recruited in response to period of deferment and grazing pressure.

failed to meet these requirements, the consequence was fewer recruited seedlings.

There was no significant difference in number of recruited white clover seedlings between wet and dry sites. Also, between herbicide treatments, no differences emerged (P = 0.3660) (Table 9). It would appear that seedling recruitment is influenced by amount of space available for these seedlings to develop. Moisture differences within the site per se may have very little influence.

Disease Attack

Leaf Rust and Phoma Leafspots

Leaf rusts, caused by Uromyces trifolii var trifolii-repentis (Liro) Arth. and leafspots, caused by Phoma sp. were the two most prevalent cool season (early spring) diseases on white clover foliage, including leaf petioles. Figures 24 and 25 show disease attack scores jointly since these diseases occurred simultaneously. Grazing pressure had a linear effect upon disease attack (P = 0.0496) as shown in Appendix Tables 27 and 28. The response of period of deferment was linear (P = 0.0001) but there was no quadratic effect (P > 0.05).

The highest disease attack was recorded at the combination of the lightest grazing pressure and longest period of deferment. The logical explanation for this is that the more lax grazing management resulted in heavier thatch of residue which could have acted as a source of inoculum for the development of disease the following spring. There were no differences in disease attack between the sites and between herbicide treatments (Table 10).

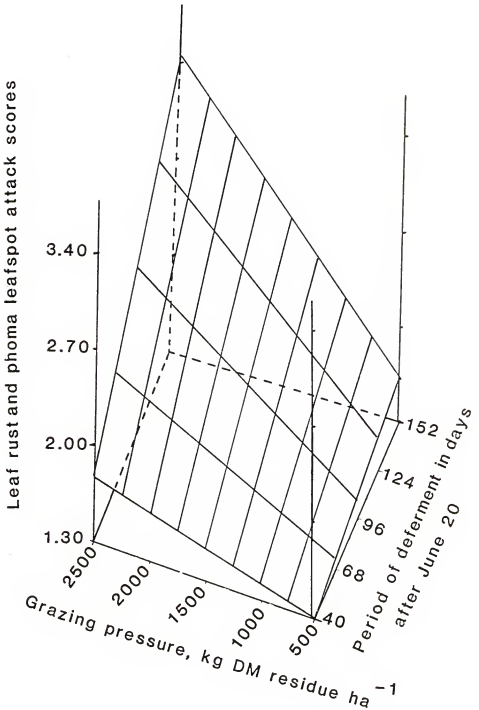


Fig. 24. Surface plot of leaf rust and phoma leafspot attack scores (on 0 to 5 scale) in response to period of deferment and grazing pressure.

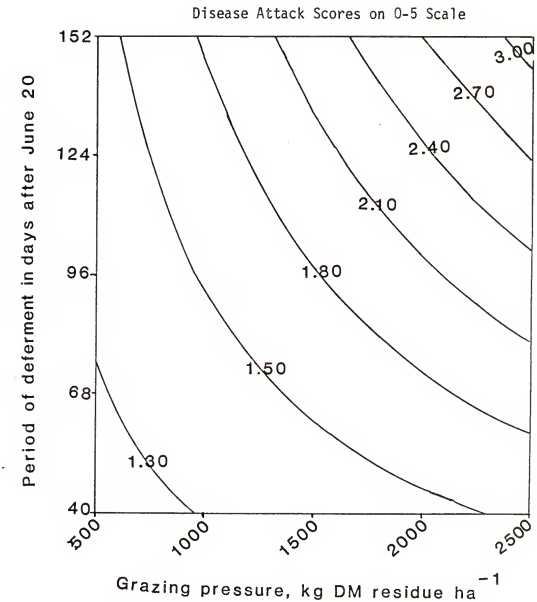


Fig. 25. Contour of leaf rust and phoma leafspot attack scores (On 0 to 5 scale) in response to period of deferment and grazing pressure.

Table 10. White clover leaf rust and Phoma leafspot, root and stolon rot diseases attack scores (0-5) on dry and wet sites and on herbicide treated subplots.

Parameter	1982			1983		
	Between sites					
	Wet		Dry	Wet		Dry
Leaf rust and Phoma leafspots	-		-	1.02 a*		1.08 a
Root and stolon rots	1.89 a		1.61 a	-		-
	Between herbicide treatments					
	Control	Banvel	Furadan	Control	Banvel	Furadan
Leaf rust and Phoma leafspots	-	-	-	1.13 a	1.03 a	1.00 a
Root and stolon rots	1.66 a	1.76 a	1.84 a	-	-	-

*Values within the row and year that are followed by the same letter are not statistically different at P = 0.05 level.

Root and Stolon Rot Diseases

The response of root and stolon rot diseases caused by Fusarium oxysporium Schlecht., Phythium middletonii and Sclerotium rolfsii Sacc. is presented in Figs. 26 and 27. It is a characteristic saddle point type of response. Both the linear functions (PD and GP) were significant (P = 0.0007 and 0.0001, respectively) as well as their quadratic functions (P = 0.0007 and 0.0139, respectively), but the interaction was not significant (Appendix Tables 29 and 30).

In response to period of deferment a maximum point is depicted at 68-96 days. Obviously, up to this point, September, a lot of stolon bruising and pulling had taken place, from the grazing process. This, coupled with the hot humid climate prevailing up to this date, was conducive to a complex of rot diseases. The response to grazing pressure, on the other hand, shows the highest attacks at both the heaviest and lightest grazing pressures. No logical explanation can be offered for this type of response, although it would appear there was much bruising and trampling of stolons at the heaviest grazing pressure. At the lightest grazing pressure, the micro-climatic conditions beneath the thick residue could have enhanced rot disease development.

Stolon death and replacement is a continuous process in white clover stands and gaps in the crop cover tend to be filled by spread from surviving plants and stolons. It is probable that the clover rot disease infection, even if not directly contributing to stolon death, adversely affected the plant's ability to survive. There was, however, no evidence of either increased stolon death or reduced recovery associated with the diseases in this study, but these effects

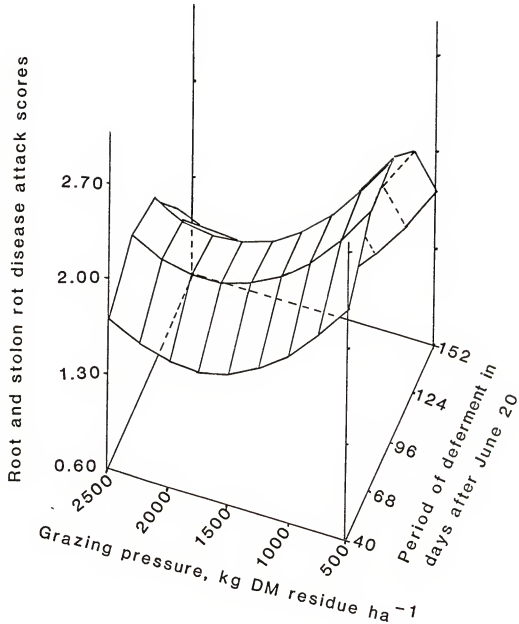


Fig. 25. Surface plot of root and stolon rot disease attack scores (on 0 to 5 scale) in response to period of deferment and grazing pressure.

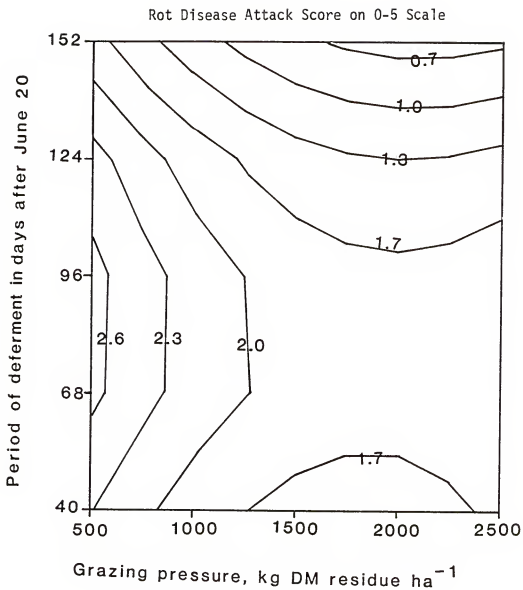


Fig. 27. Contour plot of root and stolon rot disease attack scores (on 0 to 5 scale) in response to period of deferment and grazing pressure.

may operate at levels of infection much higher than those recorded or as the cumulative effects on the plant. Scott and Evans (1980) have seen the rot disease complex devastate clover stands, forage yield and seed yield when the disease persisted in the soil and increased due to the build-up of inocula.

Differences between sites and herbicide treatments were not significant (Table 10).

Ground Cover

White Clover Ground Cover

The heaviest grazing pressure resulted in the highest percent white clover ground cover ($P = 0.0001$). This was in combination with short periods of deferment (Figs. 28, 29, 30, and 31). In both years, there was a linear response to period of deferment ($P = 0.0071$ and 0.0001, respectively) and grazing pressure ($P = 0.0001$ and 0.0001, respectively). In each year, there were no quadratic effects PD^2 and GP^2). An interaction (PD x GP) was found only in 1983 (Appendix Tables 31, 32, 33, and 34).

In 1982, the wetter site had a denser white clover ground cover ($P = 0.0001$) as shown in Table 11. The wetter site in 1983 resulted in a denser but not higher ground cover than the drier site ($P = 0.2990$). The subplots that had received Banvel® application resulted in lower white clover cover ($P = 0.0004$) in 1982 but not in 1983 ($P = 0.9194$). Because they contained predominantly seedling clover, the clover stands in these subplots did not have extensively developed stolons to give an effective ground cover.

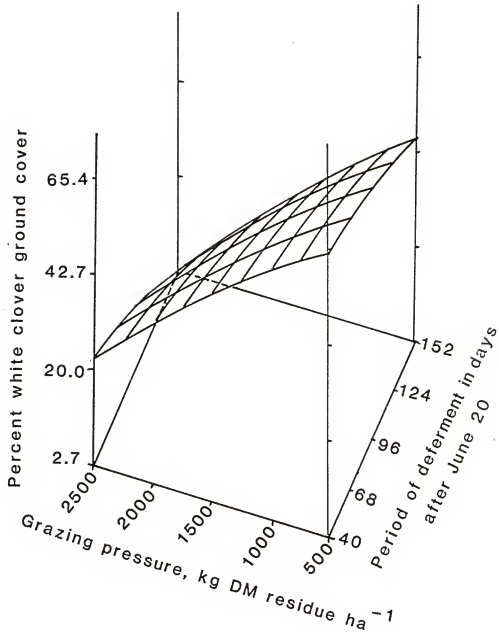


Fig. 28. Surface plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1982.

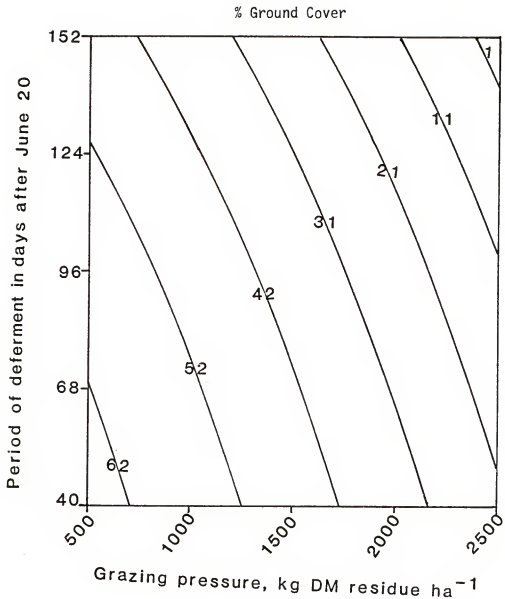


Fig. 29. Contour plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1982.

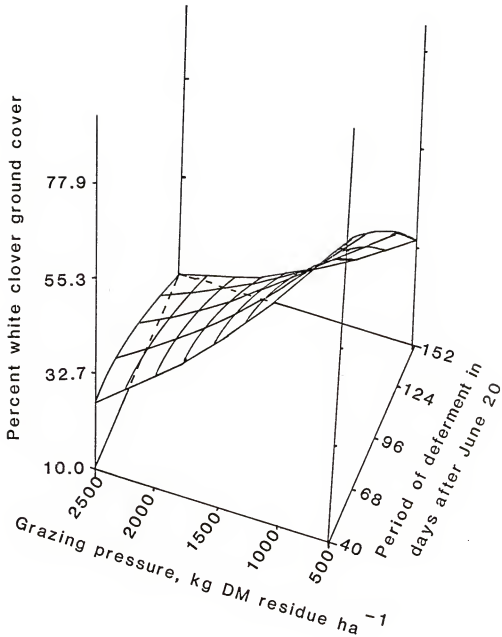


Fig. 30. Surface plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1983.

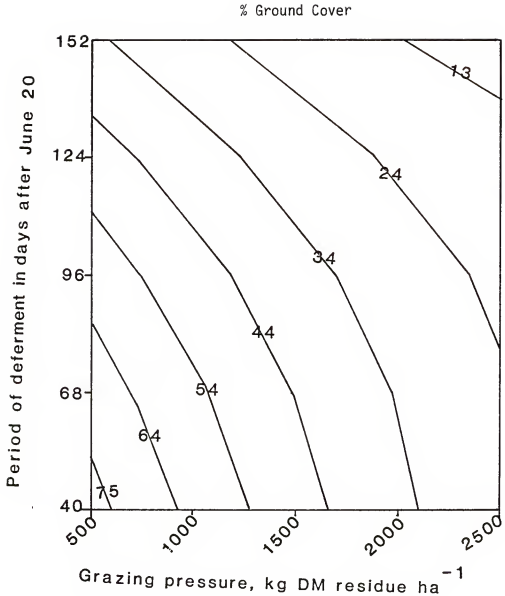


Fig. 31. Contour plot of white clover percent ground cover in response to period of deferment and grazing pressure for April 1983.

Table 11. White clover and cool season weeds percent ground cover on wet and dry sites and on herbicide treated subplots.

Parameter	Year					
	1982			1983		
	Between sites					
	Wet		Dry	Wet		Dry
White clover cover	50 a*		35 b	39 a		36 a
Weed cover	-		-	12 a		19 b
	Between herbicide treatments					
	Control	Banvel	Furadan	Control	Banvel	Furadan
White clover cover	52 a	33 b	44 a	39 a	33 a	40 a
Weed cover	-	-	-	14 a	15 a	18 a

*Values within row and year that are followed by the same letter are not statistically different at P = 0.05 level.

Cool Season Weed Species Percent Ground Cover

A combination of heaviest grazing pressure and shortest period of deferment resulted in the sparsest weed ground cover. The weeds were mostly cool season grasses and broadleaf herbs that in some cases included ryegrass (Lolium multiflorum), Bromus spp., red clover (Trifolium pratense), Brassica spp., birdsfoot trefoil (Lotus corniculatus), and other wild species.

Increased grazing pressure increased the percent ground cover of weeds ($P = 0.0034$) and period of deferment had a quadratic effect ($P = 0.0151$) and there was an interaction between PD and GP ($P = 0.0057$) (Figs. 32 and 33). The difference in weed cover was significantly affected by soil moisture differences. The drier site had a higher weed cover ($P = 0.0015$) but the herbicide treatments had little effect ($P = 0.1545$) as shown in Table 11 and Appendix Tables 35 and 36. Weed cover, it appears, was inversely related to white clover cover.

Pest Attack

Population of Grazing Snails

The grazing snail, Polygyra cereolus Muhlfeld and Arthropod populations have been known to be influenced by sward management (Purvis and Curry, 1981). Figures 34 and 35 depict the response of the grazing snails' population to period of deferment and grazing pressure. Lowest numbers of snails were recorded at the longest period of deferment and the lowest grazing pressure. There was a linear response to grazing pressure ($P = 0.0009$) and a quadratic response to period of

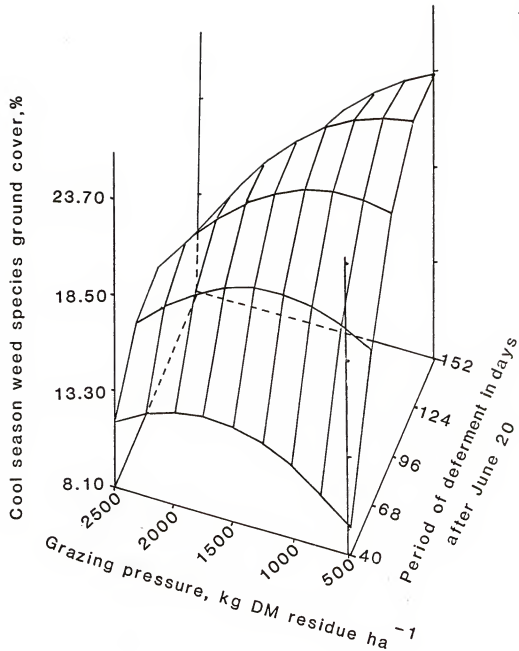


Fig. 32. Surface plot of cool season weed species percent ground cover in response to period of deferment and grazing pressure.

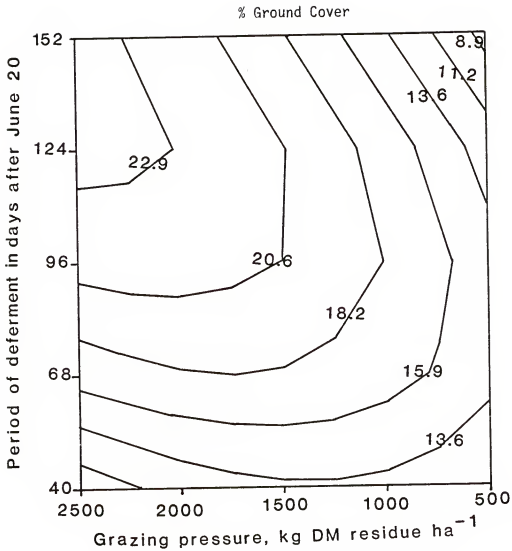


Fig. 33. Contour plot of cool season weed species percent ground cover in response to period of deferment and grazing pressure.

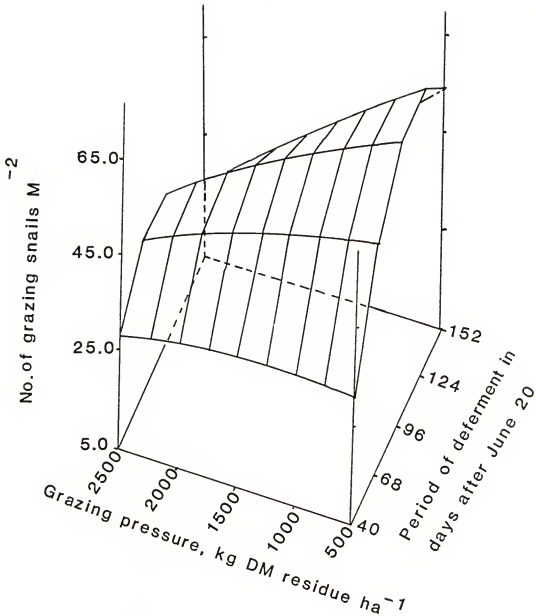


Fig. 34. Surface plot of grazing snails populations in response to period of deferment and grazing pressure.

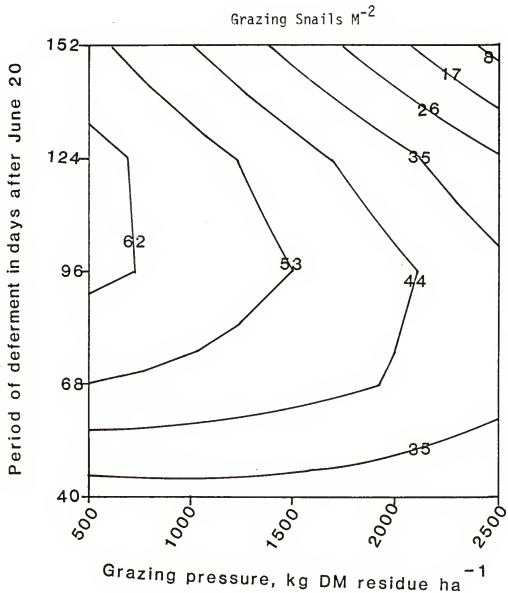


Fig. 35. Contour plot of grazing snails population in response to period of deferment and grazing pressure.

deferment (P = 0.0016). There was also an interaction (P = 0.0181) as shown in Appendix Table 37. The relatively low snail populations at the combination of shortest periods of deferment and heaviest grazing pressure (Fig. 35) is ascribed to the near depletion of vegetation cover and a more open canopy, which might have proved unfavorable to the snails at this grazing management. Less intensively and infrequently grazed pastures, on the other hand, resulted in poor clover stands and could have resulted in horizontal movements of snails away from these swards.

Although the difference between wet and dry sites was not statistically significant (Table 12), it is likely that the drier environment was unfavorable to snails. The lack of response between wet and dry sites in this case can be ascribed to the error arising from diurnal variation in movements of these snails, both horizontally and vertically in the soil and debris. There were fewer snails in the subplots which received the Banvel® application (P = 0.0046) (Appendix Table 38). Elimination of the clover plants by the Banvel® may have cut-off the snails' food supply (Crawford-Sidebotham, 1972) and probably also removed a more effective shade otherwise provided by the white clover components. This is in agreement with Kalmbacher et al. (1979) findings who reported fewer snails in bahiagrass-without-legume swards.

Leafeaters and Leaf Weevil Attack

The response of leafeater and leaf weevil attack to grazing management is shown in Figs. 36 and 37. There was no linear and quadratic effect to period of deferment (P = 0.8014 and 0.2563, respectively).

Table 12. White clover pest attack scores (leafeaters and leaf weevils on 0-5 scale) and grazing snails number m-2 on wet and dry sites and on herbicide treated subplots.

Parameter	Year					
	1982			1983		
	Between sites					
	Wet		Dry	Wet		Dry
Leafeaters and leaf weevils	-		-	1.36 a		1.44 a
No. grazing snails m^{-2}	43.5 a*		36.6 a	-		-
	Between herbicide treatments					
	Control	Banvel	Furadan	Control	Banvel	Furadan
Leafeaters and leaf weevils	-	-	-	1.45 a	1.35 a	1.40 a
No. grazing snails m^{-2}	51.8 a	21.2 b	47.2 a	-	-	-

*Values within the row and year and followed by the same letter are not stastically different at P = 0.05 level.

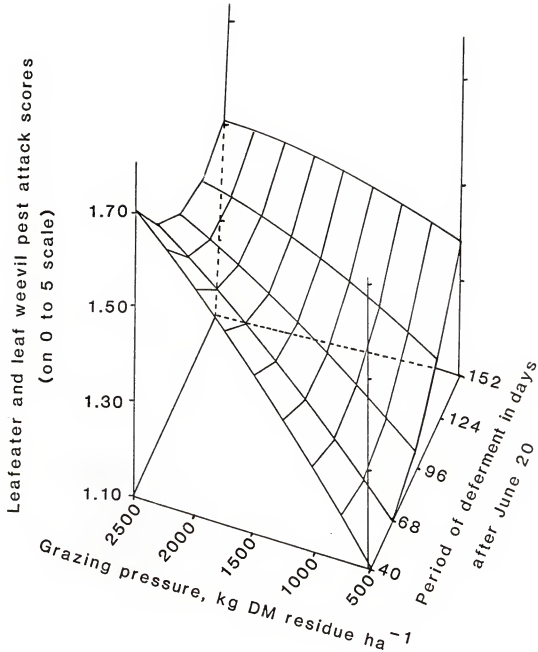


Fig. 36. Surface plot of leaf eater and leaf weevil pest attack scores on white clover in response to period of deferment and grazing pressure.

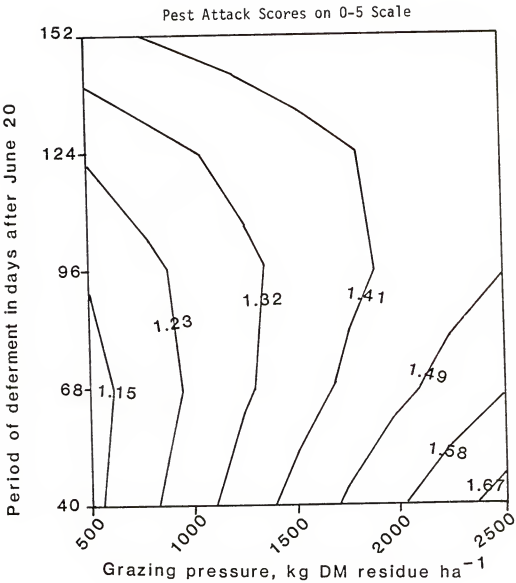


Fig. 37. Contour plot of leaf eater and leaf weevil pest attack scores on white clover in response to period of deferment and grazing pressure.

Increased grazing pressure resulted in decreased pest attack (P = 0.0009) but there was no quadratic (GP^2) effect (P = 0.7805) and no interaction (P = 0.0712). The differences in pest attack between sites and herbicide treatments were small (Appendix Tables 39 and 40; Table 12).

Although the nature of the pests is not known, it would appear that their attack was positively associated with those areas in which white clover gave the highest forage yield and where it perennated most. These happened to be the moist areas because the correlation of pest attack with soil moisture was high, positive, and statistically significant ($r^2 = 0.74$ and PROB>/R/ = 0.0001). These were probably the areas in which these pests perennated, laid their eggs, and caused most of the damage.

Early Preclusion of Grazing

Table 13 shows the opposite effect of closing the pasture early in the summer and fall on spring production and disease and pest attack situation of white clover. There was a remarkable increase in total forage production of the heavily grazed pastures and especially those at short periods of deferment when precluded from grazing early in summer and fall. This was because of a more effective white clover contribution to yield. However, those from which grazing was shut-off early resulted in increased pest and disease attack.

It is most likely that these caged-off pastures served as pest- and disease-breeding islands. They showed more fully developed clover early in the winter months, but their disease and pest attacks were also noticeable early in spring. It would have been an advantage to close

Table 13. Total available forage, white clover yield, pest attack and disease attack score percentage increases over grazed pasture in spots excluded from grazing early in summer and fall.

Treatments	Increase in mean total forage yield	Increase in mean white clover yield	Increase in mean pest attack scores	Increase in mean disease attack scores
	%			
Period of deferment (days)				
40	64	49	36	98
68	41	35	36	88
96	29	28	41	80
124	18	25	63	50
152	14	16	14	-6
Grazing pressure (DM residue, kg ha^{-1})				
500	52	42	33	55
100	47	43	88	38
1500	30	24	29	91
2000	22	25	13	100
2500	14	20	30	26

these pastures early in summer and fall if the pastures were grazed earlier in the winter-spring to cut down on the diseases and pests. This management system is synomymous with stock piling for mid-winter/early-spring grazing, in which the white clover that has been given an early chance to develop in the late summer-fall period provides the bulk of quality forage.

Total Non-Structural Carbohydrates and Protein

The influence of the previous summer-fall grazing management, with reference to period of deferment and grazing pressure on early spring total non-structural carbohydrates (TNC) and crude protein (CP) contents of white clover stolons was minimal (Appendix Tables 41 and 42). The response to period of deferment and grazing pressure was not significant. This lack of response may mean that other factors have a greater influence upon TNC and CP. In spite of seasonal fluctuations, they varied considerably diurnally also in response to environmental changes.

Shoots, such as stolons, depend upon roots to furnish necessary water and essential mineral elements for use in photosynthesis and in growth processes during the spring growth flush. Limiting the activity of the root system relative to the activity of the shoot would be expected to result in an increased level of free carbohydrates which would influence an increase in reserve carbohydrate (Buxton and Wedin, 1970). Probably no differences occurred to grazing pressure and period of deferment because there was no differential responses to constantly changing environmental conditions, such as temperature. What was significant was the fact that such environmental conditions

as soil moisture seemed to have a significant effect on both TNC and CP content of stolons. Correlations are shown in Table 14. While soil moisture was positively associated with CP content, it was negatively correlated with TNC of stolons. In wetter sites in which seasonal growth may have been shortened by moisture stress, there was a reduced amount of TNC in the stolons because these reserves were utilized in growth processes. The negative correlation of TNC with CP may mean that either serves as a substitute for the other during stress periods to provide the energy required for growth. Such environmental factors as shading normally resulted in reduced carbohydrates reserves and root to shoot ratios. Carbohydrate levels were also influenced by climatic and nutrient factors, normally in a manner inversely related to growth rate.

Table 14. Linear correlation coefficients between TNC and CP content of white clover stolons with soil moisture content.

Dependent variables	Independent variables		
	Soil moisture	White clover TNC content	White clover CP content
White clover TNC content	r^2 = -0.42 PROB>/R/=0.0001*	--	r^2 = -0.64 PROB>/R/=0.0013
White clover CP content	r^2 = 0.74 PROB>/R/=0.0001	r^2 = -0.64 PROB>/R/=0.0013	--

* PROB>/R/ values < 0.05 are statistically significant.

CHAPTER V
SUMMARY AND CONCLUSIONS

Soil Moisture Differences on the Site

There were marked soil moisture differences within the experimental site. The middle experimental units of 9 through 18, for example, showed significant differences. These were the pastures or experimental units that showed a high water table and thus ponding during the months of July to September. Other experimental units, which were well drained showed some severe moisture stress for white clover plants especially during months of insufficient precipitation.

Total Available Forage in Spring

Total available forage in spring increased with increasing grazing pressure. The highest amount of forage was obtained at the 500 kg ha^{-1} level of grazing pressure. The response to period of deferment was a typical maximum point with a peak at the 96 to 124 days period of deferment. Increased forage with increasing grazing pressure and intermediate periods of deferment were ascribed to more effective white clover contribution to the total available forage.

The wet site gave significantly higher amounts of forage. Furadan® treated subplots gave the highest amount of forage, but Banvel®-treated subplots gave the lowest amounts. This was due to the predominance of seedling white clover in these latter subplots, which did not contribute so effectively to total available forage.

White Clover Spring Available Forage

White clover forage increased with increasing levels of grazing pressure. The greatest amounts of white clover forage was obtained at the 500 kg ha^{-1} grazing pressure level. However, the response to period of deferment was a typical maximum point. The greatest amounts of forage were obtained at the 68 to 96 days period of deferment. White clover forage appeared to be directly influenced by summer-fall grazing management through its effect on soil seed reserves, number of seedlings recruited, and especially ground cover, but the influence of live-over white clover plants in summer-fall was not very obvious.

Because the Banvel®-treated plots only had volunteer or seedling white clover, they gave the smallest amount of forage. The wetter site, for its better survival potential, resulted in larger amounts of white clover forage.

Surivial Potential of White Clover

A combination of heavy grazing pressure (least amount of residue) and short to intermediate periods of deferment resulted in largest amounts of white clover soil seed reserves. The more pasture residue resulting from long periods of deferment and light grazing pressure levels produced correspondingly less readily germinable white clover soil seed. This was reflected in low soil seed recoveries from the gerination recovery procedure used. Soil seed reserves recovered by the procedure used in this study appear adequate to re-vegetate the areas where chances for white clover plants to live through the summer were curtailed by Banvel® application. However,

the preliminary data on these soil seed reserves cannot be placed in proper perspective as far as persistence is concerned, but they do suggest the need for more detailed studies in this field. The patterns of survival, emergence, and replenishment of these seed reserves would greatly assist in understanding the persistence patterns of legume components in association with tropical grasses.

Seedlings recruited, perennating plants, and ground cover of white clover were relatively low with the long periods of deferment and light grazing pressure. While the wetter site resulted in a denser white clover cover and better survival of white clover plants, this advantage was not very obvious with respect to soil seed reserves and seedling recruitment which were similar for both dry and wet sites. White clover yield appeared to be more associated with high survival potential in terms of soil seed reserves, seedling recruitment, and percent ground cover. The influence, therefore, of summer-fall grazing management (grazing pressure and period of deferment) on white clover spring forage production was through its effect on these survival mechanisms.

White clover yield and survival potential, including population of clover plants perennating through the summer-fall period were inversely related to cool season weed species ground cover. Therefore, any grazing management strategy that favored good survival potential and white clover yield such as heavy grazing pressure and intermediate to short periods of deferment reduced the ingress of these weed species in the pasture association.

Pest Attack and Grazing Snails Population

The heaviest grazing pressure level of 500 kg ha^{-1} residue and short period of deferment resulted in significantly small grazing snail populations. Probably the more open residue at this grazing management strategy was an unfavorable environment for these snails. Since there were relatively few white clover plants at the lightest grazing pressure, it was not surprising that in response to period of deferment, the highest number of grazing snails were at the combination of heaviest to intermediate grazing pressures and short to intermediate periods of deferment. This grazing management provided both food supply from the white clover component and an effective shade.

With respect to the leafeater and leaf weevil pests, the least attack was obtained at the combination of shortest period of deferment and heaviest grazing pressure. The influence of soil moisture difference between sites and herbicide treatment of both leaf pests and grazing snails was less apparent.

Disease Attack

Decreasing grazing pressure and increasing period of deferment resulted in increased leaf rust and phoma leafspot attack. The intermediate period of deferment (68 to 96 days) and increasing grazing pressure resulted in increased root and stolon-rot disease attack. There was, however, no evidence of either increased stolon death or reduced recovery associated with these diseases, but these effects may operate at levels of infection much higher than those recorded in this

study. Differences in disease attack between site, on the one hand, and between herbicide treatments, were not significantly high enough.

Early Preclusion of Grazing

While early preclusion of grazing in the summer-fall period resulted in increased white clover forage yield in the following spring, unless this forage was grazed early in mid-to-late winter/early spring period, the preclusion resulted in increased pest and disease attack beside the early development opportunity it gave to the white clover. The increased white clover forage yield with early preclusion was especially obvious at the combination of short periods of deferment and heavy grazing pressure.

Total Non-Structural Carbohydrates and Crude Protein

Summer-fall grazing management had no effect on white clover stolon TNC and CP contents the following spring. There was a significant positive relationship between soil moisture with both TNC and CP content, but there was an inverse highly significant relationship between TNC and CP contents.

The salient features of the current study with some practical implications are as follows:

1. A combination of heavy grazing pressure (500 kg DM of post-grazing residue ha^{-1}) and intermediate periods of deferment (68 to 96 days from 20 June) during the summer-fall period, results in large amounts of white clover forage in the following spring. This is attributed to a dense clover and low weed ground cover, culminating in

effective contribution by the clover to total available forage in the pasture system.

2. Increasing grazing pressure (reduced amounts of post-grazing residue) and short to intermediate summer-fall grazing periods of deferment results in an open sward in which clover plants are able to perennate because of reduced competition from the residue. The open-sward environment encourages profuse clover branching and hence large amounts of seed production for the clover component. It provides an optimum environment for clover seedling emergence and establishment in the fall. It also reduces the opportunity for pest and disease infestation and carry-over from season to season.

3. It appears that the primary mechanism for the survival of the white clover component in bahiagrass-based pastures is the adequacy of clover seeds in the system, which enables annual revegetation of the sward through annual seedling recruitment. It appears also that adequate soil moisture enhances the opportunity for perennation of white clover.

4. While summer-fall grazing management significantly influences the perennation ability of the clover component, it does not, however, appear to influence the organic reserve contents such as total non-structural carbohydrates (TNC) and crude protein (CP) in the white clover stolons and roots; the reserves upon which individual plant survival ability might depend.

5. Lax grazing management, as afforded by large amounts of post-grazing residue and long periods of deferment, encourages pest and disease attack to the white clover component.

APPENDIX

Table 15. Analysis of variance for total available forage (kg DM ha^{-1}) in spring 1982, without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	5486828.90	7.51	0.0001
PD	1	5550.82	0.01	0.9307
GP	1	14178994.05	19.41	0.0001
PD^2	1	11329104.90	15.51	0.0001
GP^2	1	108759.39	0.15	0.7002
PD x GP	1	1811735.35	2.48	0.1178
Residual (Error)	126	730468.47		
Corrected total	131			

*P > F values <0.05 are statistically significant.

Table 16. Analysis of variance for total available forage (kg DM ha-1) in spring 1982, with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	2402834.95	3.10	0.0011
Site	1	4528065.94	5.84	0.0172
T	1	5110646.01	6.59	0.0115
PD	1	5550.82	0.01	0.9327
GP	1	14178994.05	18.29	0.0001
Site x T	1	409500.10	0.53	0.4688
Site x PD	1	53249.28	0.07	0.7937
Site x GP	1	172490.05	0.22	0.6380
T x PD	1	155982.77	0.20	0.6546
T x GP	1	79717.23	0.10	0.7490
Site x PD x GP	1	1622765.58	2.09	0.1506
T x PD x GP	1	114222.61	0.15	0.7018
Residual (Error)	120	775349.90		
Corrected total	131			
Mean = 3585				

*P > F values < 0.05 are statistically significant.

Table 17. Analysis of variance for total available forage (kg DM ha^{-1}) in spring 1983, without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	4903626.45	7.53	0.0001
PD	1	246459.49	0.38	0.5395
GP	1	15362847.08	23.60	0.0001
PD^2	1	7543395.09	11.59	0.0009
GP^2	1	370363.26	0.57	0.4521
PD x GP	1	995067.33	1.53	0.2187
Residual (Error)	126	651095.11		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 18. Analysis of variance for total available forage (kg DM ha^{-1}) in 1983 with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	2026962.10	2.89	0.0022
Site	1	3363538.19	4.79	0.0306
T	1	1787520.05	2.55	0.1132
PD	1	246459.48	0.35	0.5547
GP	1	15362847.08	21.88	0.0001
Site x T	1	230113.64	0.33	0.5681
Site x PD	1	449996.16	0.64	0.4250
Site x GP	1	33418.08	0.05	0.8277
T x PD	1	319103.89	0.45	0.5015
T x GP	1	190.39	0.00	0.9869
Site x PD x GP	1	410025.78	0.58	0.4463
T x PD x GP	1	93370.34	0.13	0.7160
Residual (Error)	120	702162.77		
Corrected total	131			
Mean = 3570				

*P > F values < 0.005 are statistically significant.

Table 19. Analysis of variance for white clover forage (kg DM ha^{-1}) in spring 1982, without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	4833511.47	23.95	0.0001
PD	1	7514101.16	37.23	0.0001
GP	1	12993577.70	64.38	0.0001
PD^2	1	3595895.26	17.82	0.0001
GP^2	1	56060.24	0.28	0.5991
PD x GP	1	7923.01	0.04	0.8433
Residual (Error)	126	201827.56		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 20. Analysis of variance for white clover forage (kg DM ha^{-1}) in spring 1982, with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	1916403.35	8.06	0.0001
Site	1	76416.48	0.32	0.5717
T	1	378853.14	1.59	0.2092
PD	1	7514101.16	31.62	0.0001
GP	1	12993577.70	54.68	0.0001
Site x T	1	276.55	0.00	0.9728
Site x PD	1	3224.39	0.01	0.9075
Site x GP	1	8906.70	0.04	0.8468
T x PD	1	17723.08	0.07	0.7853
T x GP	1	55969.92	0.24	0.6283
Site x PD x GP	1	1270.40	0.01	0.9418
T x PD x GP	1	30106.38	0.13	0.7225
Residual (Error)	120	237645.03		
Corrected total	131			
Mean = 883				

*P > F values < 0.05 are statistically significant.

Table 21. Analysis of variance for white clover spring forage (kg DM ha^{-1}) in 1983, without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	3711891.42	18.04	0.0001
PD	1	2305832.32	11.21	0.0011
GP	1	13456800.05	65.41	0.0001
PD^2	1	2367608.97	11.51	0.0009
GP^2	1	328482.64	1.60	0.2087
PD x GP	1	100733.11	0.49	0.4854
Residual (Error)	126	205721.37		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 22. Analysis of variance for white clover spring forage (kg DM ha^{-1}) in 1983, with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	1523922.13	6.60	0.0001
Site	1	470770.37	2.04	0.1560
T	1	256500.01	1.11	0.2941
PD	1	2305832.32	9.98	0.0020
GP	1	13456800.05	58.26	0.0001
Site x T	1	18299.56	0.08	0.7788
Site x PD	1	78787.71	0.34	0.5603
Site x GP	1	21136.61	0.09	0.7628
T x PD	1	108199.69	0.47	0.4950
T x GP	1	398.77	0.00	0.9669
Site x PD x GP	1	15895.00	0.07	0.7935
T x PD x GP	1	30523.30	0.13	0.7169
Residual (Error)	120	230976.72		
Corrected total	131			
Mean = 1063				

*P > F values < 0.05 are statistically significant.

Table 23. Analysis of variance for perennating white clover plants m^{-2} without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	590.48	9.81	0.0001
PD	1	2705.16	44.92	0.0001
GP	1	1.27	0.02	0.8847
PD^2	1	36.26	0.60	0.4392
GP^2	1	197.93	3.29	0.0722
PD x GP	1	11.77	0.20	0.6592
Residual (Error)	126	60.22		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 24. Analysis of variance for perennating white clover plants m^{-2} with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	269.7970	4.28	0.0001
Site	1	111.4857	1.77	0.1863
T	1	11.1613	0.18	0.6748
PD	1	2705.1592	42.87	0.0001
GP	1	1.2718	0.02	0.8873
Site x T	1	20.6998	0.33	0.5679
Site x PD	1	29.5015	0.47	0.4955
Site x GP	1	3.2984	0.05	0.8195
T x PD	1	13.1655	0.21	0.6487
T x GP	1	22.8960	0.36	0.5481
Site x PD x GP	1	5.4437	0.09	0.7695
T x PD x GP	1	43.6845	0.69	0.4070
Residual (Error)	120			
Corrected total	131			
Mean = 5.86				

*P > F values < 0.05 are statistically significant.

Table 25. Analysis of variance for white clover seedlings recruited m^{-2} without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	3381473.09	14.85	0.0001
PD	1	6484040.01	28.48	0.0001
GP	1	7114516.01	31.24	0.0001
PD^2	1	359772.14	1.58	0.2111
GP^2	1	434542.47	1.91	0.1696
PD x GP	1	2514494.79	11.04	0.0012
Residual (Error)	126	227709.64		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 26. Analysis of variance for number of white clover seedlings recruited (m^{-2}) with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	1568200.95	6.64	0.0001
Site	1	137352.76	0.58	0.4473
T	1	194486.01	0.82	0.3660
PD	1	6484040.01	27.45	0.0001
GP	1	7114516.01	30.12	0.0001
Site x T	1	272729.56	1.15	0.2848
Site x PD	1	68411.54	0.29	0.5915
Site x GP	1	3766.21	0.02	0.8997
T x PD	1	97962.48	0.41	0.5208
T x GP	1	172730.94	0.73	0.3942
Site x PD x GP	1	2739294.27	10.75	0.0014
T x PD x GP	1	164920.66	0.70	0.4051
Residual (Error)	120	236238.08		
Corrected total	131			
Mean = 362.56				

*P > F values < 0.05 are statistically significant.

Table 27. Analysis of variance for leaf rust and Phoma leaf spot disease attacks (0-5 scale) without subplot treatments (T) for 1983.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	3.37	6.62	0.0001
PD	1	10.41	20.42	0.0001
GP	1	2.00	3.93	0.0496
PD^2	1	0.55	1.08	0.3005
GP^2	1	3.07	6.01	0.0156
PD x GP	1	0.85	1.67	0.1981
Residual (Error)	126	0.51		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 28. Analysis of variance for leaf rust and Phoma leaf spot disease attacks (0-5 scale) with subplot treatments (T) for 1983.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	1.3791	2.91	0.0071
Site	1	0.1212	0.22	0.6395
T	1	0.3438	0.63	0.4306
PD	1	10.4135	18.95	0.0001
GP	1	2.0032	3.64	0.0586
Site x T	1	0.0710	0.13	0.7199
Site x PD	1	0.0032	0.01	0.9393
Site x GP	1	0.9263	1.69	0.1967
T x PD	1	0.3077	0.56	0.4558
T x GP	1	0.0769	0.14	0.7090
Site x PD x GP	1	0.8081	1.47	0.2277
T x PD x GP	1	0.0959	0.17	0.6769
Residual (Error)	120	0.5497		
Corrected total	131			
Mean = 1.05				

*P > F values < 0.05 are statistically significant.

Table 29. Analysis of variance for Fusarium and Phythium root and stolon rot diseases attack (scored on 0-5 scale) without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	8.57	9.87	0.0001
PD	1	10.41	11.99	0.0007
GP	1	15.72	18.09	0.0001
PD^2	1	10.60	12.21	0.0007
GP^2	1	5.40	6.22	0.0139
PD x GP	1	0.73	0.84	0.3618
Residual (Error)	126	0.87		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 30. Analysis of variance for Fusarium and Pythium root and stolon rot diseases attack (score on 0-5 scale) with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	3.0098	3.03	0.0014
Site	1	2.5928	2.61	0.1087
T	1	0.7273	0.73	0.3938
PD	1	10.4135	10.49	0.0016
GP	1	15.7051	15.82	0.0001
Site x T	1	0.0455	0.05	0.8309
Site x PD	1	0.0288	0.03	0.8649
Site x GP	1	1.2821	1.29	0.2581
T x PD	1	1.1550	1.16	0.2829
T x GP	1	0.2704	0.27	0.6027
Site x PD x GP	1	0.8490	0.86	0.3570
T x PD x GP	1	0.0385	0.04	0.8443
Residual (Error)	120	0.9928		
Corrected total	131			
Mean = 1.75				

*P > F values < 0.05 are statistically significant.

Table 31. Analysis of variance for white clover percent ground cover without subplot treatments (T) in 1982.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	5651.69	12.52	0.0001
PD	1	3387.13	7.50	0.0071
GP	1	24415.38	54.09	0.0001
PD^2	1	153.50	0.34	0.5608
GP^2	1	185.74	0.41	0.5224
PD x GP	1	116.69	0.26	0.6120
Residual (Error)	126	451.42		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 32. Analysis of variance for white clover percent ground cover with subplot treatments (T) in 1982.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	3364.48	8.39	0.0001
Site	1	7025.52	17.52	0.0001
T	1	6252.55	13.12	0.0004
PD	1	3387.13	8.45	0.0044
GP	1	24415.38	60.88	0.0001
Site x T	1	0.73	0.00	0.9661
Site x PD	1	353.28	0.88	0.3499
Site x GP	1	34.67	0.09	0.7693
T x PD	1	90.24	0.22	0.6361
T x GP	1	353.08	0.88	0.3500
Site x PD x GP	1	78.40	0.20	0.6592
T x PD x GP	1	18.26	0.05	0.8314
Residual(Error)	120	401.07		
Corrected total	131			
Mean = 42.6				

*P > F values < 0.05 are statistically significant.

Table 33. Analysis of variance for white clover percent ground cover without subplot treatments (T) in 1983.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	9724.84	40.25	0.0001
PD	1	16955.13	70.18	0.0001
GP	1	28692.51	118.76	0.0001
PD^2	1	319.26	1.32	0.2525
GP^2	1	349.32	1.45	0.2314
PD x GP	1	2307.96	9.55	0.0025
Residual (Error)	126	241.60		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 34. Analysis of variance for white clover percent ground cover with subplot treatments (T) for 1983.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	4474.80	17.99	0.0001
Site	1	270.61	1.09	0.2900
T	1	2.56	0.01	0.9194
PD	1	16955.13	68.18	0.0001
GP	1	28692.51	115.38	0.0001
Site x T	1	505.92	2.03	0.1564
Site x PD	1	187.71	0.75	0.3867
Site x GP	1	41.65	0.17	0.6831
T x PD	1	46.17	0.19	0.6673
T x GP	1	3.77	0.02	0.9022
Site x PD x GP	1	2402.40	9.66	0.0024
T x PD xGP	1	114.34	0.46	0.4990
Residual (Error)	120	248.69		
Corrected total	131			
Mean = 37.3				

*P > F values < 0.05 are statistically significant.

Table 35. Analysis of variance for cool season weed species percent ground cover without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	636.46	5.44	0.0002
PD	1	322.02	2.75	0.0995
GP	1	1043.94	8.93	0.0034
PD^2	1	709.78	6.07	0.0151
GP^2	1	179.98	1.54	0.2170
PD x GP	1	926.56	7.93	0.0057
Residual (Error)	125	116.91		
Corrected total	131			

*P > F values < 0.05 are stastically significant.

Table 36. Analysis of variance for cool season weed species percent ground cover with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	359.32	3.09	0.0012
Site	1	1236.50	10.63	0.0015
T	1	238.92	2.05	0.1545
PD	1	334.84	2.88	0.0924
GP	1	1020.95	8.78	0.0037
Site x T	1	39.56	0.34	0.5609
Site x PD	1	20.03	0.26	0.6123
Site x GP	1	4.34	0.04	0.8472
T x PD	1	4.62	0.04	0.8424
T x GP	1	51.00	0.44	0.5092
Site x PD x GP	1	891.85	7.67	0.0065
T x PD x GP	1	99.98	0.86	0.3558
Residual (Error)	119†	116.34		
Corrected total	131			
Mean = 15.54				

*P > F values < 0.05 are stastically significant.
†There was one missing value.

Table 37. Analysis of variance for number of grazing snails (m^2) without subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	6563.28	5.55	0.0001
PD	1	50.88	0.04	0.8360
GP	1	13627.71	11.53	0.0009
PD^2	1	12244.46	10.36	0.0016
GP^2	1	109.12	0.09	0.7618
PD x GP	1	6784.25	5.74	0.0181
Residual (Error)	126	1182.43		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 38. Analysis of variance for number of grazing snails (m^{-2}) with subplot treatments (T).

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	2291.16	1.76	0.0691
Site	1	1554.61	1.19	0.2773
T	1	5702.81	4.37	0.0046
PD	1	50.88	0.04	0.8483
GP	1	13627.71	10.44	0.0016
Site x T	1	294.56	0.23	0.6356
Site x PD	1	388.15	0.30	0.5865
Site x GP	1	361.85	0.28	0.5995
T x PD	1	73.92	0.06	0.8123
T x GP	1	913.92	0.70	0.4043
Site x PD x GP	1	6433.21	4.93	0.0283
T x PD x GP	1	1026.43	0.79	0.3769
Residual (Error)	120	1304.99		
Corrected Total	131			
Mean = 40.07				

*P > F values < 0.05 are statistically significant.

Table 39. Analysis of variance for leafeaters and leaf weevils attack scores (on 0-5 scale) without subplot treatments (T) for 1983.

Source	Degree of freedom	Mean square	F value	P > F*
Model	5	0.6591	3.27	0.0084
PD	1	0.0128	0.06	0.8014
GP	1	2.3365	11.58	0.0009
PD^2	1	0.2624	1.30	0.2563
GP^2	1	0.0157	0.08	0.7805
PD x GP	1	0.6679	3.31	0.0712
Residual (Error)	126	0.2018		
Corrected total	131			

*P > F values < 0.05 are statistically significant.

Table 40. Analysis of variance for leaf eaters and leaf weevils attack scores (on 0-5 scale) with subplot treatments (T) for 1983.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	11	0.4182	2.08	0.0266
Site	1	0.1894	0.94	0.3336
T	1	0.0710	0.35	0.5533
PD	1	0.0128	0.06	0.8010
GP	1	2.3365	11.62	0.0009
Site x T	1	0.1392	0.69	0.4069
Site x PD	1	0.3878	1.93	0.1674
Site x GP	1	0.0513	0.26	0.6144
T x PD	1	0.2031	1.01	0.3168
T x GP	1	0.1454	0.72	0.3967
Site x PD x GP	1	0.8284	4.12	0.0446
T x PD x GP	1	0.2353	1.17	0.2814
Residual (Error)	120	0.2010		
Corrected total	131			
Mean = 1.40				

*P > F values < 0.05 are statistically significant.

Table 41. Analysis of variance for TNC content (on DM basis) for main treatments only.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	138.88	1.49	0.1994
PD	1	45.13	0.48	0.4885
GP	1	391.34	4.19	0.0532
PD^2	1	177.20	1.90	0.1713
GP^2	1	24.22	0.26	0.6117
PD x GP	1	56.48	0.60	0.4385
Residual (Error)	103	93.38		
Corrected total	108†			

*P > F values < 0.05 are statistically significant.
†There was one missing plot.

Table 42. Analysis of variance for crude protein content (on DM basis) for main treatments only.

Source	Degrees of freedom	Mean square	F value	P > F*
Model	5	1.42	0.60	0.7012
PD	1	3.13	1.33	0.2514
GP	1	1.35	0.57	0.4507
PD^2	1	1.86	0.79	0.3762
GP^2	1	0.36	0.15	0.6976
PD x GP	1	0.38	0.16	0.6873
Residual (Error)	104	2.35		
Corrected total	109			

*P > F values < 0.05 are statistically significant.

LITERATURE CITED

Ahlgren, G. H., and R. F. Fuellman. 1950. Ladino clover. Advances Agron. 2:207-232.

_____, and H. B. A. Sprague. 1940. A survey of variables in white clover (T. repens L.) and its relation to pasture improvement. Bull. 575, New Jersey Agric. Exp. Stn.

Akiyama, T., and S. Kubo. 1978. Treading on the grassland-photosynthesis and dry matter production of native grasses. Bull. Nat. Grassl. Res. Inst. 12:23-31.

Alberda, T. 1957. The effects of cutting, light intensity, and night temperature on growth and soluble carbohydrate content of Lolium perenne L. Plant Soil 8:199-230.

Andrade, J. M. 1979. Smutgrass, Sporobolus poiretii (Roem. and Schultz) Hitch. control with grazing management systems. Ph. D. dissertation, University of Florida, Gainesville, FL. Diss. Abstr. 40:1457-B.

Balaam, L. N. 1975. Response surface designs. P. 11-32 In V. J. Bofinger and J. L. Wheeler (eds.) Development in the field experiment design and analysis. Bull. 50 Commonwealth Bureau of Pasture and Field Crops.

Barnard, C. 1972. Register of Australian herbage plant cultuvars. CSIRO, Canberra, Australia.

Barton, L. V. 1962. The germination of weed seeds. Weed Sci. 10:174-182.

Bazaar, F. A. 1970. Secondary dormancy in seeds of the common ragweed, Ambrosia artemisiifolia. Bull. Torrey Bot. Club 97:302-305.

_____. 1979. The physiological ecology of plant succession. Ann. Rev. Ecol. Syst. 10:351-371.

Beinhart, G. 1962. Effects of temperature and light intensity on CO_2 uptake, respiration and growth of white clover. Plant Physiol. 37:709-715.

_____. 1963. Effects of environment on meristematic development, leaf area and growth of white clover. Crop Sci. 3:209-213.

_____, P. B. Gibson, J. E. Haplin, and E. A. Hollowell. 1963. Selection and evaluation of white clover clones. II. The role of midsummer diseases. Crop Sci. 3:89-92.

Blaser, R. E., R. H. Brown, and H. T. Bryant. 1966. The relationship between carbohydrate accumulation and growth of grasses under different microclimates. Proc. 10th Int. Grassl. Congr. pp. 147-150.

_____, and G. B. Killinger. 1950. Life history studies of Louisiana white clover (Trifolium repens L.) I. Seed germination as related to temperature, pasture management and adaptation. Agron. J. 42: 215-220.

Blue, W. G. 1979. Forage production and N contents and soil changes during 25 years of continuous white clover-Pensacola bahiagrass growth on a Florida Spodosol. Agron. J. 71:795-798.

Bogdan, A. V. 1977. Tropical pasture and fodder plants. Longmans, London.

Booysen, P. de V., N. M. Tainton, and J. D. Scott. 1963. Shoot apex development in grasses and its importance in grassland management. Herbage Abstr. 33:209-212.

Brown, D. B., and C. S. Hoveland. 1972. A study of the position of grass growing points in two species under different systems of management. N. Z. J. Agric. Res. 15:7-18.

Brown, K. R., and P. S. Evans. 1973. Animal treading--A review of the work of the late D. B. Edmond. N. Z. J. Exp. Agric. 1:217-226.

Brougham, R. W. 1959. The effects of frequency and intensity of grazing on the productivity of a pasture of short rotation ryegrass and white clover. N. Z. J. Agric. Res. 2:1232-1248.

_____. 1960. The effects of frequent hard grazings at different times of the year on the productivity and species yields of a grass-clover pasture. N. Z. J. Agric. Res. 3:125-136.

_____, P. R. Ball, and W. M. Williams. 1978. The ecology and management of white clover-based pastures. In J. R. Wilson (ed.) Plant relations in pastures. CSIRO, East Melbourne, Australia.

Bryan, W. W., and T. R. Evans. 1973. Effects of soils, fertilizers and stocking rates on pastures and beef production on the Wallum of southeastern Queensland. I. Botanical composition and chemical effects on plants and soils. Aust. J. Exp. Agric. Anim. Husb. 13:516-529.

Burton, G. W. 1967. A search for the origin of Pensacola bahiagrass. Econ. Bot. 21:379-382.

Burton, G. W., F. E. Jackson, and F. E. Knox. 1959. The influence of light reduction upon the production, persistence and chemical composition of coastal bermudagrass, Cynodon dactylon. Agron. J. 51:537-541.

Buxton, D. R., and W. F. Wedin. 1970. Establishment of perennial forages. 1. Subsequent yields. 2. Subsequent root development. Agron. J. 62:93-97; 97-100.

Cameron, D. G. 1969. The effect of Paspalum on the production pattern of Ladino white clover under irrigation on heavy clay soils in Central Queensland. Ql's. J. Agric. Anim. Sci. 26:373-384.

Carlisle, V. W., C. T. Hallmark, F. Sodek, R. E. Caldwell, L. C. Hammond, and V. E. Berkheiser. 1981. Characterization data for selected Florida soils. University of Florida, Gainesville, FL. IFAS in Coop. with USDA Soil Conserv. Serv.

Carrier, L., and K. S. Bort. 1966. The history of Kentucky bluegrass and white clover in the United States. J. Am. Soc. Agron. 8: 256-266.

Christiansen, S., K. J. Boote, and E. B. Blazey. 1982. Total nonstructural carbohydrate (TNC) procedure. University of Florida, Agron. Dept., Mimeo, Gainesville, FL.

Cochran, R. W., and G. M. Cox. 1957. Experimental design. 2nd Ed. Wiley, New York.

Coelho, R. W. 1979. Regrowth of ryegrass as influenced by five different rest periods. Ph.D. Dissertation, University of Florida, Gainesville, FL. Diss. Abstr. 40:1459-B.

Cook, C. W. 1966. Carbohydrate reserves in plants. Utah Res. Ser. 31, Logan, Utah. pp. 47.

Council, K. A., and J. T. Helwig (eds.). 1981. Edition SAS/graph user's guide. SAS Inst., Inc., North Carolina.

Crawford-Sidebotham, T. J. 1972. The role of snails and slugs in maintenance of the cyanogenesis polymorphisms of Lotus corniculatus and Trifolium repens. Heredity. 24:423-430.

Crowder, L. V. 1960. The response of white clover varieties grown at high elevation in Colombia. Agron. J. 52:608-609.

_____, and J. P. Craigmiles. 1960. Comparison of Ladino and Louisiana white clover in three grass sods. Agron. J. 52:379-381.

Curll, M. L. 1982. The grass and clover content of pastures grazed by sheep. Herbage Abstr. 25:403-411.

Curll, M. L., and R. J. Wilkins. 1981. Frequency and severity of defoliation of grass and clover by sheep at different stocking rates. Grass and Forage Sci. 37:291-297.

_____, and _____. 1983. The comparative effects of defoliation, treading and excreta on a Lolium perenne-Trifolium repens pasture grazed by sheep. J. Agric. Sci., Cambridge. 100:451-460.

Daday, H. 1958. Gene frequencies in wild populations of Trifolium repens L. III. World distribution. Heredity. 12:169-184.

Daer, T., and E. E. Willard. 1981. Total non structural carbohydrate trends in Blue bunch wheatgrass related to growth and phenology. J. Range Manage. 34:377-379.

Dart, P. J., and D. C. Wildon. 1970. Nodulation and nitrogen fixation by Vigna sinensis and Vicia atropurpurea: The influence of concentration, form and site of application of combined nitrogen. Aust. J. Agric. Res. 21:45-56.

Daugherty, R. W. 1956. Bloat in ruminants. Yearbook Agric., USDA, Washington, D. C. 1956:108-113.

Davidson, R. L. 1969. Effect of root/leaf temperature differentials on root/shoot ratios in some pasture grasses and clover. Ann. Bot. 33:561-569.

Davila-Calderon, C. 1981. Management systems for improving the summer survival of white clover (Trifolium repens). M. S. Thesis, University of Florida, Gainesville, FL.

Dean, C. E. 1975. Evaluation of two plant types in white clover (Trifolium repens) and changes in plant type brought about by natural crossing. Soil Crop Sci. Soc. Fla. Proc. 26:124-130.

Dietrick, E. J. 1961. An improved back motor fan for sampling for insect population. J. Econ. Entomol. 54:394-395.

Dobson, J. W., and E. R. Beaty. 1977. Forage yields of five perennial grasses grown with and without white clover at four nitrogen rates. J. Range Manage. 30:461-465.

_____, and _____. 1980. Contributions of white clover to the N, P, and Ca concentration of perennial grasses. J. Range Manage. 32:107-110.

Donnelly, E. C., and C. S. Hoveland. 1966. Interspecific reseeding Vicia hybrids for use on summer perennial grass sods in southeastern U.S.A. Proc. 10th Int. Grassl. Congr., Helsinki, Finland. pp. 679-683.

Edmond, D. B. 1964. Some effects of sheep treading on the growth of 10 pasture species. N. Z. J. Agric. Res. 7:1-16.

Emeades, D. C., and K. M. Goh. 1978. Symbiotic nitrogen fixation in a sequence of pastures of increasing age measured by ^{15}N dilution technique. N. Z. J. Agric. Res. 21:626-628.

Gardener, C. J. 1982. Population dynamics and stability of Stylosanthes hamata cv. verano in grazed pastures. Aust. J. Agric. Res. 33:63-74.

Gibson, P. B., and E. A. Hollowell. 1966. White clover. USDA Handbook 314. Washington, D.C.

Graber, L. F. 1931. Food reserves in relation to other factors limiting the growth of grasses. Plant Physiol. 6:43-71.

Haggar, R. J., W. Holmes, and P. Innes. 1963. White clover seed production. I. The effect of defoliation and fertilizer treatment on flowering and seed yield from ryegrass/white clover swards. J. Br. Grassl. Soc. 18:97-103.

Haines, C. E., H. L. Chapman, R. J. Allen, and R. W. Kidder. 1961. Comparison of major perennial pasture forages of the Everglades. Fla. Agric. Exp. Stn. Rep. 272.

Haplin, J. E., P. B. Gibson, G. Beinhart, and E. A. Hollowell. 1963. Evaluation of white clover clones. II. The role of midsummer diseases. Crop Sci. 3:87-89.

Harper, J. L. 1977. Population biology of plants. Academic Press, London.

Harrington, G. T. 1916. Agricultural value of impermeable seeds. J. Agric. Res. 6:761-797.

Harris, W. 1968. Pasture seed mixtures, competition and productivity. Proc. N. Z. Grassl. Assoc. 30:143-152.

_____, A. F. Boyd, L. B. Anderson, E. W. Vartha, and D. L. Ryan. 1977. Performance of four ryegrass cultivars under cutting. N. Z. J. Exp. Agric. 5:391-395.

_____, and V. J. Thomas. 1973. Competition among pasture plants. III. Effects of frequency and height of cutting on competition between white clover and two ryegrass cultivars. N. Z. J. Agric. Res. 16:49-58.

Hay, M. J. M. 1983. Seasonal variation in the distribution of white clover (Trifolium repens L.) stolons among three horizontal strata in two grazed swards. N. Z. J. Agric. Res. 26:29-34.

Heylar, K. R., and A. J. Anderson. 1970. Responses of five pasture species to phosphorus, lime and nitrogen on the infertile acid soil with a high phosphate sorption capacity. Aust. J. Agric. Res. 21:677-692.

Helwig, J. T., and K. A. Council. 1979. SAS user's guide. SAS Inst. Inc., Raleigh, North Carolina.

Hodges, E. M., D. W. Jones, and W. G. Kirk. 1953. Winter clovers. University of Florida, IFAS Agric. Stn. Bull. 157.

Hodgkinson, K. C., and O. B. Williams. 1979. Adaptation in forage plants. In Proc. Symp. Genetics Resources of Forage Plants, CSIRO, Townsville, Queensland, Australia.

Hojjati, S. M., R. A. McCreery, and W. E. Adams. 1968. Effects of nitrogen and potassium fertilization, irrigation and clipping interval on the chemical composition of coastal bermudagrass (Cynodon dactylon L.) Pers. I. Total available carbohydrates. Agron. J. 60:617-619.

Hollowell, E. A. 1951. Ladino white clovers. In The science of grassland farming. Iowa State University Press, Ames, Iowa.

_____. 1966. White clover, Trifolium repens L. annual or perennial? Proc. 10th Int. Grassl. Congr., Helsinki, Finland. pp. 184-187.

Holmes, W., and D. T. A. Aldrich. 1959. Nitrogen fertilizers and production of crops and grasses. Proc. Nutr. Soc. 16:9-14.

Humphreys, L. R. 1974. A guide to better pastures for the tropics and sub-tropics. 3rd Ed., Wright Stephenson, Victoria, Australia.

Hunt, O. J. 1964. An evaluation of visual weight estimating method of determining botanical composition of forage plots. Agron. J. 56:73-76.

Hutchinson, K. H. 1970. The persistence of perennial species under intensive grazing in a cool temperate environment. Proc. 11th Int. Grassl. Congr., Surfer's Paradise, Australia. pp. 611-614.

Hyde, E. O. C., and F. E. T. Suckling. 1953. Dormant seeds of clover and other legumes in agricultural soils. N. Z. J. Sci. Tech. 34:375-385.

Irwin, J. A. G., and R. M. Jones. 1977. The role of fungi and nematodes as factors associated with death of white clover (Trifolium repens) stolons over summer in southeastern Queensland. Aust. J. Exp. Agric. Anim. Husb. 17:789-794.

Iverson, L. R., and M. K. Wali. 1982. Buried, viable seeds and their relation to revegetation after surface mining. J. Range Manage. 35:648-652.

Jackman, R. H., and M. C. H. Mouat. 1970. The effect of browntop (Agrostis tenuis Sibth) and increasing phosphorus deficiency on the growth of white clover (Trifolium repens L.). Proc. 11th Int. Grassl. Congr., Surfer's Paradise, Australia. pp. 354-357.

Jameson, D. A. 1964. Responses of individual plants to harvesting. Bot. Rev. 29:532-594.

Jewess, O. R. 1972. Vegetative growth. In C. R. W. Spedding and E. C. Diekmahns (eds.) Grasses and legumes in British agriculture. Bull. 49, CAB, England.

Johansen, C., P. C. Kerridge, P. E. Luck, B. G. Cook, K. F. Lowe, and H. Ostrowski. 1977. The residual effect of molybdenum fertilizer on growth of tropical pasture legumes in a sub-tropical environment. Aust. J. Exp. Agric. Anim. Husb. 17:961-968.

Jones, R. J., and R. M. Jones. 1978. The ecology of siratro-based pastures. P. 353-367. In J. R. Wilson (ed.) Plant relations in pastures, CSIRO, Melbourne, Australia.

Jones, R. M. 1969. Mortality of some tropical grasses and legumes following frosting in the first winter after sowing. Trop. Grassl. 3:57-63.

_____. 1980. Survival of seedlings and primary taproots of white clover (Trifolium repens) in subtropical pastures in south-east Queensland. Trop. Grassl. 14:19-22.

_____. 1981. Studies on the population dynamics of siratro: The fate of siratro seeds following oversowing into sub-tropical pastures. Trop. Grassl. 15:95-101.

_____. 1982. White clover (Trifolium repens) in subtropical south-east Queensland. I. Some effects of site, season and management practices on the population dynamics of white clover. Trop. Grassl. 16:118-127.

_____, and T. R. Evans. 1977. Soil seed levels of Lotononis bainesii, Desmodium intortum, and Trifolium repens in subtropical pastures. J. Aust. Inst. Agric. Sci. 43:164-166.

_____, and J. J. Mott. 1980. Population dynamics in grazed pastures. Trop. Grassl. 14:218-224.

Kalmbacher, R. S., D. R. Minnick, and F. G. Martin. 1979. Destruction of sod-seeded legume seedlings by the snail (Polygyra cereolus). Agron. J. 71:365-368.

Kalmbacher, R. S., P. Mislevy, and F. G. Martin. 1980. Sod-seeding bahiagrass in winter with three temperate legumes. Agron. J. 72:114-118.

Killinger, G. B. 1970. White clover, red clover and ryegrass for north central Florida. Soil Crop Sci. Soc. Fla. Proc. 30: 331-336.

_____. 1977. Agronomic studies. P. 3-8. In M. Koger (ed.) Pasture programs and beef production in north central Florida. Fla. Agric. Exp. Stn. Tech. Bull. 789.

Kiwamura, A., and S. Yamasaki. 1972. Studies on the soil adaptability of warm-season grasses. I. Effect of phosphorus level in mineral soils on the early growth of bahiagrass. Bull. Shikoki Agric. Exp. Stn. No. 24:109-122.

Koger, M., W. G. Blue, G. B. Killinger, R. E. L. Green, H. C. Harris, J. M. Meyers, A. C. Wornick, and N. Gammon. 1961. Beef production, soil and forage analysis and economic returns from eight pasture productions in north central Florida. Fla. Agric. Exp. Stn. Bull. 631.

_____, _____, _____, K. M. Myers, N. Gammon, A. C. Warnick, and J. R. Crockett. 1970. Production response and economic returns from five pasture programs in north central Florida. Fla. Agric. Exp. Stn. Tech. Bull. no. 740.

_____. 1977. General discussion of results over a 20 year period. In M. Koger (ed.) Pasture programs and beef cattle breeding systems for beef production in north central Florida. Fla. Agric. Exp. Stn. Tech. Bull. 789.

Kretschmer, A. E. 1958. Growth of Louisiana S1 white clover seedlings as influenced by soil additions of lime and phosphate. Soil Crop Sci. Soc. Fla. Proc. 18:136-149.

_____. 1976. Growth and adaptability of Centrosema species in south Florida. Soil Crop Sci. Soc. Fla. Proc. 36:164-168.

Kydd, D. D. 1966. The effect of intensive sheep stocking over a five year period on the development and production of the sward. I. Sward structure and botanical composition. J. Br. Grassl. Soc. 21:284-288.

Leach, G. J. 1978. The ecology of lucerne. P. 290-308. In J. R. Wilson (ed.) Plant relations in pastures. CSIRO, Melbourne, Australia.

Lee, C. T., and D. Smith. 1972. Influence of nitrogen fertilizer on stands yields of herbage and protein and nitrogenous fractions of field grown alfalfa. Agron. J. 64:527-530.

Leffel, R. C., and P. B. Gibson. 1978. White clover. P. 167-176. In M. E. Heath, D. S. Metcalf, and R. F. Barnes (eds.) Forages, the science of grassland agriculture. Iowa State University Press, Ames, Iowa.

Littell, C., and G. O. Mott. 1974. Computer assisted design and analysis of response surface experiments in agronomy. Soil Crop Sci. Soc. Fla. Proc. 34:94-97.

Lopez-Nunez, J. 1982. Grazing management for improving the summer usrvival and the spring production of white clover (Trifolium repens L.) in subtropical pastures. M. S. Thesis, University of Florida, Gainesville, FL.

Mackay, J. H. E. 1973. Register of herbage plants cultivars. 1. Clover. Trifolium semipilosum Pres. var. glabrescens Gillet (Kenya white clover) cv. Safari. J. Aust. Inst. Agric. Sci. 39: 274-276.

Mannetje, L'. t. 1978. P. 63-93 In L'. t. Mannetje (ed.) Measurement of grassland vegetation and animal production. CAB Bull. 52, Berkshire, England.

May, L. H. 1960. The utilization of carbohydrate reserves in pasture plants after defoliation. Herb. Abstr. 30:239-245.

McCarthy, G., and F. E. Emery. 1894. Some leguminous plants. N. C. Agric. Exp. Stn. Bull. 98.

McWilliams, J. R. 1978. Response of pasture plants to temperature. P. 17-34. In J. R. Wilson (ed.) Plant relations in pastures. CSIRO, Melbourne, Australia.

Menke, J. W., and M. J. Trlica. 1981. Carbohydrate reserves, phenology and growth cycles on nine Colorado range species. J. Range Manage. 34:269-277.

Menzies, S. A. 1973. Proc. 26th New Zealand Weed and Pest Control Conf. p. 122.

Miller, D. F. 1958. Composition of cereal grains and forages. Nat. Acad. Sci. Nat. Res. Counc. Pub. 585.

Mills, P. F. L., M. G. W. Rodel, and J. N. Boultwood. 1973. Effects of applied nitrogen on herbage production of four grasses receiving supplementary irrigation. Rhodesia Agric. J. 70:131-133.

Milton, W. E. J. I. 1943. The buried viable seed content of a midland calcareous clay soil. Empire J. Exp. Agric. 11:155-166.

Mitchell, K. J. 1956. Growth of pasture species under controlled environment. I. Growth at various levels of constant temperature. N. Z. J. Sci. Tech. 38:203-216.

Morrison, J., J. Reeks, P. Chapman, and R. D. Russell. 1979. Performance of white clover in different environments. P. 52-53. In G. R. I. Annual Report, Hurley, Maidenhead, Grassl. Res. Inst.

Mott, G. O. 1982. Evaluation of pastures germplasm under different grazing management alternatives. Centro Internacional Agricultura Tropical (In press).

Murtagh, G. J. 1977. Use of herbicide to reduce grass competition in a white clover sward. Trop. Grassl. 11:121-124.

O'Brien, A. D. 1970. Evaluating white clover varieties for the clarence river beef country. Trop. Grassl. 4:63-69.

Ojima, K., and T. Isawa. 1968. The variation of cabohydrates in various species of grasses and legumes. Can. J. Bot. 46:1507-1511.

Orr, S. J., and A. S. Laidlaw. 1978. The effect of nitrogen on grass and grass/clover swards under two cutting frequencies. Rec. Agric. Res. 26:41-55.

Ostrowski, H. 1972. White clover Trifolium repens in subtropical Australia--a review. Trop. Grassl. 6:97-106.

Paim, N. R., and C. E. Dean. 1976. Characteristics of cyanogenic and acyanogenic white clover plant. Soil Crop Sci. Soc. Fla. Proc. 35:18-21.

Pitman, W. D. 1983. Initial comparisons of tropical legume-bahiagrass pastures and nitrogen-fertilized bahiagrass pastures in peninsular Florida. Soil Crop Sci. Soc. Fla. Proc. 42:72-75.

Prine, G. M. 1964. Forage possibilities in the genus Arachis. Soil Crop Sci. Soc. Fla. Proc. 24:187-196.

Purvis, G., and J. P. Curry. 1981. The influence of sward management on foliage arthropod communities in a ley grassland. J. A-pl. Ecol. 18:711-725.

Reed, K. F. M. 1972. The performance of sheep grazing different pasture types. P. 193-204. In J. H. Leigh and J. C. Noble (eds.) Plants for sheep in Australia. Angus and Robertson, Sydney, Australia.

Reid, D. 1972. The effects of the long term application of a wide range of nitrogen rates on the yields from perennial ryegrass swards with and without white clover. J. Agric. Sci., Cambridge. 79:291-301.

Robinson, G. G. 1973. Management factors affecting white clover dominance in natural pastures. J. Aust. Inst. Agric. Sci. 39: 211-212.

Robinson, R. R. 1960. Germination of hard seed in Ladino white clover. Agron. J. 52:212-214.

Russell, E. S. 1973. Soil conditions and plant growth. Longmans, London.

Saldivar-Fitzmaurice, A. J. 1983. Growth analysis of Florigraze rhizoma peanut (Arachis glabrata Benth.). Ph.D. Dissertation, University of Florida, Gainesville, FL. Diss. Abstr. (in press).

Santillan, R. A., W. R. Ocumpaugh, and G. O. Mott. 1979. Estimating forage yield with a disk meter. Agron. J. 71:71-74.

Schlundt, A. F. 1977. Effects of management treatments on the botanical composition of a bahiagrass (Paspalum notatum Flugge), smutgrass (Sporobolus poiretii Roem) and white clover (Trifolium repens L.). M. S. Thesis, University of Florida, Gainesville, FL.

Schuman, G. E., M. A. Stanley, and D. Knudsen. 1973. Automated total nitrogen analysis of soil and plant samples. Soil Sci. Soc. Am. Proc. 37:480-481.

Scott, S. W., and D. R. Evans. 1980. Sclerotinia trifoliorum Erikss on white clover (Trifolium repens L.). Grass Forage Sci. 35: 159-163.

Shaw, N. H., R. M. Jones, L. A. Edye, and W. W. Bryan. 1976. Developing and testing new pastures. P. 175-193. In N. H. Shaw and W. W. Bryan (eds.) Tropical pasture research: Principles and methods. CAB Bull. 51, Berkshire, England.

Smith, A., R. A. Anortt, and J. M. Peacock. 1971. A comparison of the growth of a cut sward with that of a grazed sward, using a technique to eliminate fouling and treading. J. Br. Grassl. Soc. 26:157-162.

Smith, D. 1968. Classification of several native North American grasses as starch or fructosan accumulators in relation to taxonomy. J. Br. Grassl. Soc. 23:306-309.

_____. 1981. Removing and analyzing total nonstructural carbohydrates from plant tissue. Wisconsin Agric. Bull. R.2107.

Sproule, R. J., H. M. Shelton, and R. M. Jones. 1983. Effects of summer and winter grazing on growth habit of Kenya white clover (Trifolium semipilosum) cv. Safari in a mixed sward. Trop. Grassl. 17:25-30.

Stern, W. R., and C. M. Donald. 1962. Light relationships in grass-clover swards. Aust. J. Agric. Res. 13:599-614.

Stewart, E., and F. E. Bear. 1951. Ladino clover, its mineral requirements and chemical composition. New Jersey Agric. Exp. Stn. Bull. 759.

Stout, D. G., M. Suzuki, and B. Brooke. 1983. Nonstructural carbohydrate and crude protein in pinegrass storage tissues. J. Range Manage. 36:440-443.

Suckling. F. E. T. 1950. The passage of white clover seeds through the body of sheep and the effect on germination capacity. N. Z. Grassl. Assoc. Proc. 12th Conf. pp. 108-121.

Suzuki, S., A. Adachi, and T. Yamada. 1958. Studies on selection methods in white clover breeding. III. On the heritability of some characters in Ladino clover (In Japanese English summary) Bull. Nat. Inst. Agric. Sci. (Japan) Ser. G. No. 14:169-178.

Swetham, M. L. 1973. Grazing management. P. 85-128. In R. H. M. Langer (ed.) Pastures and pasture plants. Reed Wellington, New Zealand.

Taylor, G. B., and R. C. Rossiter. 1974. Persistence of several annual legumes in mixtures under continuous grazing in the south west of western Australia. Aust. J. Exp. Agric. Anim. Husb. 14: 632-639.

Thomson, D. J. 1977. The role of legumes in improving the quality of forage diets. Proc. Int. Meet. Anim. Prod. Temp. Grassl., Dublin. pp. 131-135.

_____. 1978. Effects of the proportion of legume in the sward on animal output. P. 101-109. In Changes in swards composition and productivity. Occasional Symp. No. 10., Br. Grassl. Soc.

Thurston, J. M. 1960. Dormancy in weed seeds. P. 69-82. In J. L. Harper (ed.) The biology of weeds. Blackwell Sci. Pub., London, U.K.

Trlica, J. M. 1977. Distribution and utilization of carbohydrates reserves in range plants. P. 74-96. In R. E. Sosebee (ed.) Rangeland plant physiology. Soc. Range Manage., Denver, Colorado.

_____, and J. S. Singh. 1979. Translocation of assimilates and creation distribution and utilization of reserves. P. 537-571. In R. A. Perry and D. W. Goodall (eds.) IBP16, Arid-land ecosystems, Vol I., Cambridge University Press, London, England.

Turkington, R., M. A. Cahn, A. Vardy, and J. L. Harper. 1979. The growth distribution and neighbour relationships of Trifolium repens in a permanent pasture. III. The establishment and growth of Trifolium repens in natural and perturbed sites. J. Ecol. 67:231-343.

USDA. 1982. Special soil survey report maps and interpretations. Alachua County, Florida. USDA Soil Conservation Service in Coop. with Florida Agric. Exp. Stn.

Valle, L. S. 1977. Changes in smutgrass (Sporobolus poiretii Roem and Schultz) Hitchc. J. ground cover induced by spraying with molasses and grazing management. Ph.D. Dissertation, University of Florida, Gainesville, FL. Diss. Abstr. 38:5131-B.

Walker, T. W., and A. F. R. Adams. 1958. Competition for sulfur in a grass-clover association. Plant and Soil 9:353-366.

_____, _____, and H. D. Orchiston. 1956. The effect of levels of calcium sulphate on the yield and composition of a grass and clover pasture. Plant and Soil. 7:290-300.

Watson, D. J. 1956. Leaf growth in relation to crop yield P. 178-190. F. L. Milthorpe (ed.) The growth of leaves. Butterworths Sci. Pub., London, England.

Weinmann, H. 1961. Total available carbohydrates in grasses and legumes. Herbage Abstr. 31:255-261.

Westbrooks, F. E., and M. B. Tesar. 1955. Taproot survival of Ladino clover. Agron. J. 47:403-410.

White, L. M. 1973. Carbohydrate reserves of grasses: A review. J. Range Manage. 26:13-18.

Whiteman, P. C. 1980. Tropical pasture science. Oxford University Press, London, U. K.

Wiersum, L. K. 1979. A comparison of the behavior of some root systems under restricted aeration. Netherland J. Agric. Sci. 27:92-98.

Widdup, K. H., and J. D. Turner. 1983. Performance of 4 white clover populations in monoculture and with ryegrass under grazing. N. Z. J. Exp. Agric. 11:27-31.

Wilkins, H. L., I. L. Lindall, R. E. Davis, and P. J. Reynolds. 1958. Free reducing acid-hydrolyzable and nutritionally significant chemical components of forage legumes. J. Agric. Food Chem. 6:369-373.

Williams, O. B. 1970. Population dynamics of two perennial grasses in Australian semi-arid grassland. J. Ecol. 58:869-875.

Wilson, J. R., and C. W. Ford. 1973. Temperature influences on the in vitro digestibility and soluble carbohydrate accumulation of tropical and temperate grasses. Aust. J. Agric. Res. 24:187-198.

Wilson, J. R., and K. P. Haydock. 1971. The comparative response of tropical and temperate grasses to varying levels of nitrogen and phosphorus nutrition. Aust. J. Agric. Res. 22:573-587.

Wolfe, E. C., and A. Lazenby. 1973a. Grass-clover relationships during pasture development. I. Effects of superphosphate. Aust. J. Exp. Agric. Anim. Husb. 13:567-574.

_____, and _____. 1973b. Grass-clover relationships during pasture development. II. Effects of nitrogen and superphosphate. Aust. J. Exp. Agric. Anim. Husb. 13:575-580.

Wolton, K. M., J. S. Brockman, and P. G. Shaw. 1970. The effects of stage of growth at defoliation on white clover in mixed swards. J. Br. Grassl. Soc. 18:213-219.

Yamada, T. 1959. Studies on drought tolerance of Ladino clover (In Japanese, English summary). Bull. Nat. Inst. Agric. Sci. (Japan), Ser. G. No. 17:143-169.

Zaleski, A. 1964. Effect of density of plant population, photoperiod, temperature and light intensity on inflorescence formation in white clover. J. Br. Grassl. Soc. 19:237-247.

BIOGRAPHICAL SKETCH

Belson "Ben" Hesten Dzowela, the author, was born on 30 August 1947, in Ntchisi District, Central Malawi. After primary schooling at Ng'ombe and Kalira in the same district, he proceeded to Likuni Boys' Secondary School, in Lilongwe District in 1964. In 1968, he was admitted to Chancellor College of the University of Malawi and 4 years later graduated with a B. Sc. in Agriculture at the University's Bunda College of Agriculture.

Upon graduation, he obtained a position with the Department of Agricultural Research of the Malawi Government's Ministry of Agriculture, working as an agronomist in-charge of Lunyangwa Agricultural Research Station, near Mzuzu, in Northern Malawi. In 1975, he was awarded a British Council Scholarship to study at Aberystwyth College of the University of Wales, in the United Kingdom. He graduated from that college in 1977, with a M.S. in Agricultural Botany, majoring in Grassland Agronomy. For his thesis research he evaluated the agronomic potential of cocksfoot (Dactylis glomerata) cultivars from Breeders' lines at the nearby Welsh Plant Breeding Station. Returning to Malawi, he continued with agronomic research in pastures and fodder crops at Chitedze Agricultural Research Station, near Lilongwe City.

In 1980, he worked as Senior Research Agronomist responsible for the local coordination of research on semi-arid crops in the World Bank/Malawi Government financed Shire Valley Agricultural Development Project, based at Ngabu, in Southern Malawi. At the close of that year, he was awarded a scholarship under the USAID/Malawi Government

Sponsorship to study pasture science in the U.S.A. He was admitted to the graduate school of the University of Florida, at Gainesville, in January 1981. He is currently a candidate for the degree of Doctor of Philosophy, and upon graduation, intends to return to Malawi to continue in his pursuits in pasture science research.

"Ben" as popularly known among close friends has been married since 1974 to Elie T. Nyamuhone. They have two children, a daughter, Madalitso, and a son, Titha.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

G. O. Mott, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. G. Blue
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

J. E. Moore
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

J. H. Conrad
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

O. C. Ruelke
Professor of Agronomy

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

April 1984

Dean, College of Agriculture

Dean for Graduate Studies and Research